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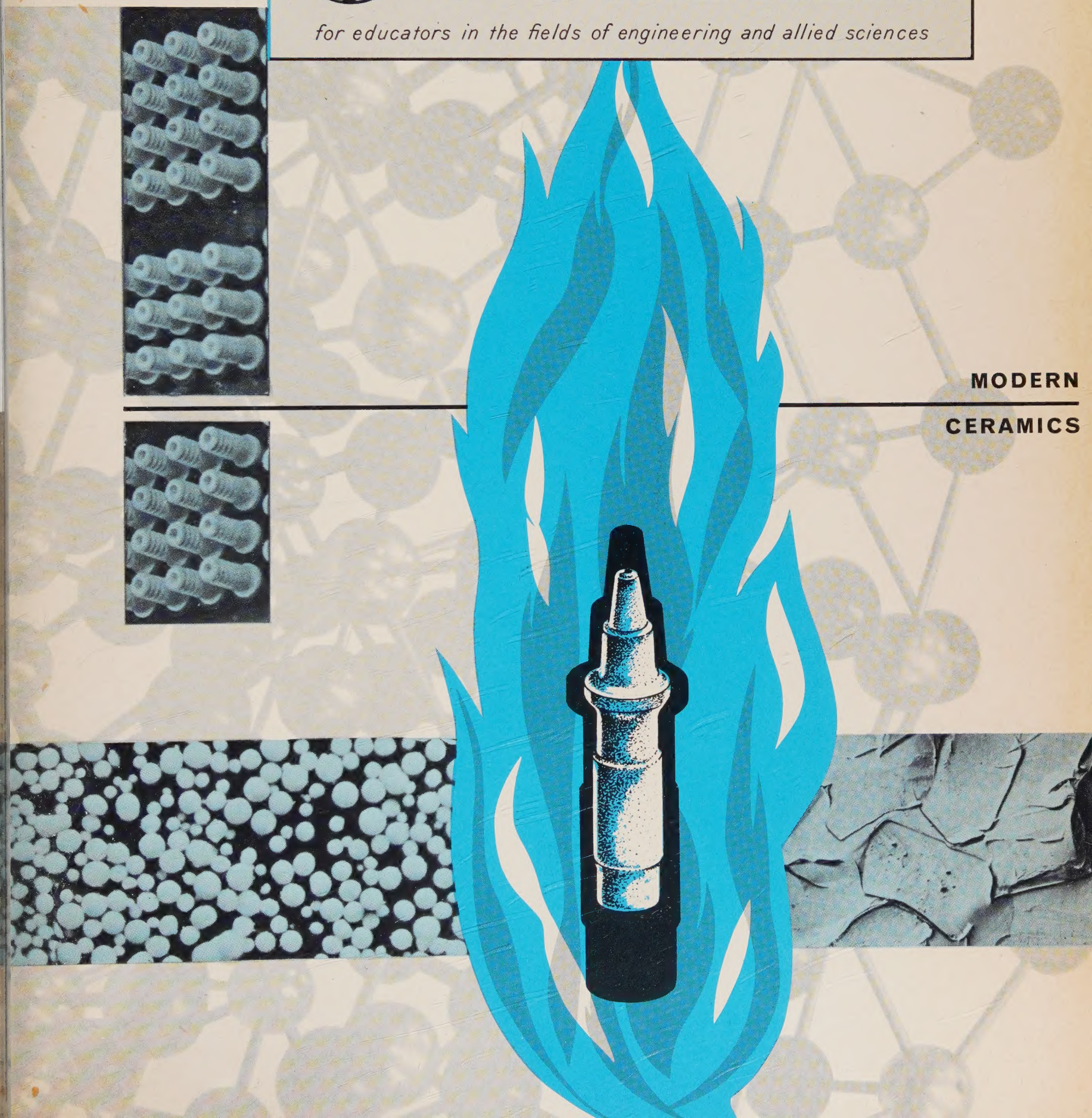
for educators in the fields of engineering and allied sciences



MODERN CERAMICS

Some Thoughts on Reliability

Out of the accelerated scientific and engineering advances of recent years has come an important concept: reliability control.

Simply defined, reliability is having a product do what it is supposed to do at the time and in the manner it is supposed to do it.

The concept of reliability is not merely a mathematical one related to parts and assemblies; it is not merely inspection and quality control. It is much broader. It spreads over every activity concerned with the conception, development, testing, manufacture, and ultimate use of a product in the service for which it is intended.

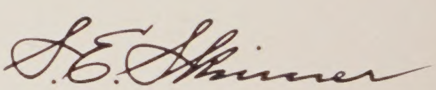
Reliability control now is given more attention than ever before for the simple reason that the need for it is imperative. For example, in the face of the more exacting performance requirements of military missiles and space exploration devices, reliability control is worth the extra effort and expense in terms of achieving reliable functioning—or preventing a wasteful failure.

The operation of an inertial guidance system in a missile illustrates the degree of reliability we are working with today. The guidance system controls the missile only during the powered portion of its flight while the missile is attaining the precise velocity necessary to hit a target. If this velocity at the instant the power is stopped is in error by as little as one foot per second out of a velocity of 24,000 feet per second, the missile will miss its target by one mile. The need is, therefore, obvious for some method of preventing errors of this type which could be caused by an unreliable component. Of course, the guidance system is only one of several critical components which must perform correctly in a successful missile, and the missile, in turn, is only one element in the weapons system that is built around it. Other elements include launching sites, logistics, and trained crews.

The reliability of a device made up of more than one critical component is the product of the reliability of each of those components. When we say that a component is 90 per cent reliable, we mean that there are 90 chances in 100 that it will perform as expected. If an end product has three components each with a reliability factor of 90 per cent, the reliability factor of the end product is not 90 per cent, but 90 times 90 times 90, or roughly 73 per cent.

For maximum performance, reliability must be built into an entire system beginning with the design stage and continuing through engineering development, parts qualification testing, production, assembly, use, and maintenance in the field. Reliability is a goal to be recognized by practicing engineers as well as today's engineering students who later on will be stepping into responsible design positions.

The reliability concept amounts to a breakthrough in the field of quality control, or, better still, quality management. In the final analysis, if this concept is to mean anything in an engineering and manufacturing organization, it must be a management philosophy and it must be deeply rooted in the thinking of everyone involved.



S. E. Skinner,
Executive Vice President

THE COVER

Ceramic materials have been important to the scientist and engineer for many years and continuing research in ceramics and processing techniques has added to their value. One phase of this research has been devoted to developing improved ceramic materials to meet the stringent requirements for spark plug insulators, the subject of this issue's cover design by artist Richard P. Renius. The background for the design shows a molecular model of alumina, the basic ceramic material used in insulators such as those produced by AC Spark Plug Division. Shown at the bottom of the front and back covers are pellets of alumina and binding materials which are the result of a process consisting of dry grinding in a ball mill, wet mixing in a blunger, and spray drying before being molded into the desired insulator shape. The insulator moldings, shown at the upper left, are then fired in a kiln. During the firing process the organic binder is burned out and a sintering process takes place which results in a shrinkage of the molding, as shown by the outline of the insulator before and after firing. At the bottom right is an electronmicrograph of a fired section of a ceramic insulator.

CONTENTS

PAPERS IN THIS ISSUE

CLASSROOM PROBLEMS

OTHER FEATURES

GENERAL MOTORS
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The GENERAL MOTORS ENGINEERING JOURNAL is published quarterly by the Educational Relations Section of the Public Relations Staff, General Motors Corporation. It is intended primarily as a medium for presenting to educators in the fields of engineering and allied sciences the results of General Motors research and engineering developments in both the product and production fields.

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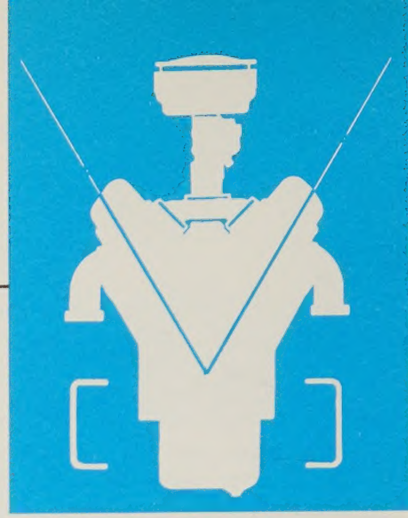
Some Design Features of a New Series of V-6 and V-12 Gasoline Engines for Truck Application



The 1960 model trucks recently introduced by GMC Truck and Coach Division represent the latest results of a long range program to develop new truck engineering concepts through a re-evaluation of truck design principles. A major part of this program was the development of a new series of high performance V-6 and V-12 gasoline engines designed to meet the needs of the trucking industry. These engines contribute to improved truck performance and service by developing maximum torque at moderate engine speeds and providing increased fuel economy, decreased engine maintenance, easy access to engine components, and a high degree of parts interchangeability between the engine models.

A FEATURE of the 1960 model trucks recently introduced by GMC Truck and Coach Division is a new series of V-6 and V-12 gasoline engines (Fig. 1). This series includes four engine models—the 305, 351, 401, and 702. These engines, all 60°V, valve-in-head type, represent one part of a broad developmental program initiated by GMC Truck and Coach to supply truck operators with equipment capable of providing economic benefits through decreased operating costs and greater ease and efficiency in transporting loads[1].

To meet the objectives of this program the engines were designed to provide high performance, maximum durability, ease of maintenance, and extensive parts interchangeability within the four engine models. Contributing to engine durability are such features as a rigid cylinder block and crankcase structure; a high velocity, high capacity coolant flow; elimination of engine hot spots; and positive lubrication through the use of rotor-type oil pumps. Also, an "over square" design of the engines (bore dimension of each greater than the stroke) holds internal friction and heat loss to a minimum, which results in less engine wear. The arrangement of engine components for easy accessibility contributes to ease of maintenance. For example, spark plugs and wires on each engine model are on the inboard side of the cylinder heads away from exhaust manifold heat.

Because each engine model is part of a family of models, many component parts are either identical or similar in design, which reduces the number of machine tools required for manufacture. Examples of identical parts are connecting rods and rocker arms. Parts of similar design are cylinder blocks, pistons, and cylinder heads. The V-6 engines have over 70 parts in common. This is especially significant to truck operators and dealers who stock replacement parts.

Cylinder Block Designed for Maximum Rigidity

The 60° cylinder block was originally designed in conformity with typical engine design practice—that is, the vertical walls of the crankcase portion of the block ended at the centerline of the crankshaft. To give the cylinder block maximum rigidity and additional stiffness, the walls were extended downward for three inches (Fig. 2). With this change, a very rigid flywheel housing-to-cylinder block bolting was attained.

The cylinder blocks for the four different engine models are machined on the same production line. The blocks for the three V-6 engines receive identical machining except for cylinder bore diameters and the provision for a camshaft idler gear spindle on the 401 block. The cylinder bores for the V-12 block require two passes, six cylinders being machined at each pass. The machining of the front and rear faces on the V-12 block is the same as for the V-6 blocks.

The 60° cylinder block also provides the basis for the design of a narrow, compact engine which lends itself to a variety of cab designs, fits easily between the frame rails, and does not interfere with front wheel or steering mechanisms (Fig. 3).

Combustion Chambers are Fully Machined

The combustion chambers are fully machined to maintain combustion chamber volume and assure equal compression ratios in all cylinders. Two different size combustion chambers of the same design are used—one size for the 305 engine model and the second size for the 351, 401, and 702 models. The same machine is used for both size chambers. Only a change in cutter diameter is required. The depth of cut and traverse of the cutter is the same for both size chambers.

The combustion chamber design used for the V-6 and V-12 engines was the last of three designs evaluated. A wedge-type chamber was the first design evaluated (Fig. 4a). Because of the shallow combustion chamber used with this type of design, there was the possibility of the valves striking the piston should false valve motion occur. This could be overcome by using valve head clearance notches in the top face of the piston. This was considered undesirable, however, and a second chamber design was evaluated. This design, known as an inverted bath tub tilted at a sideways angle of six degrees (Fig. 4b), had a combustion chamber deeper than the wedge-type design. The chamber gave adequate breathing capacity through the valves, but developmental tests showed that superior results could be obtained if the large quench area on the spark plug side of the chamber was eliminated.

Elimination of the quench area was based on the following reasoning. In general, quench areas serve two main purposes. The quench areas cool portions of the charge by providing large surface areas. When properly located, this cooling can be applied to those portions of the charge that would be the last to burn—that is, those portions farthest from the electrodes of the spark plug. Thus, the quench areas reduce the tendency for end-gases to auto-ignite. Quench areas

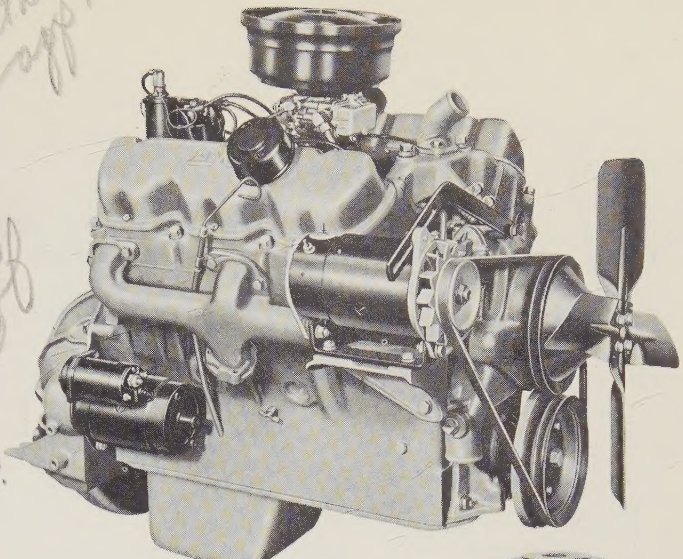
By RICHARD C. BALMER
GMC Truck and
Coach Division

(Murphy's Law) Very unsuitable for insulation hi stress app. lowest level of reliability because of all the parts used.

One significant feature: maximum torque at low rpm

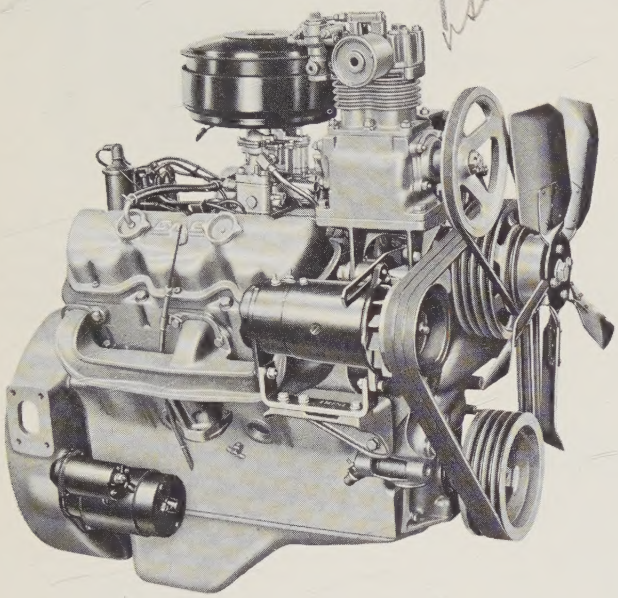
a

305



b

351



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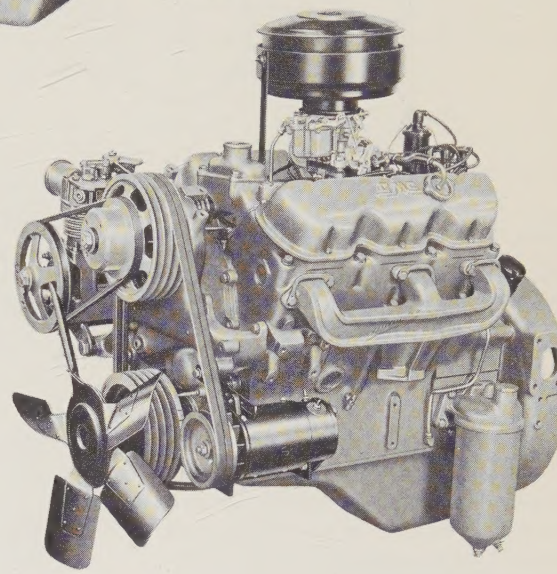
401



ENGINE TYPE	ENGINE MODEL	BORE (IN.)	STROKE (IN.)	DIS-PLACE-MENT (CU IN.)
V-6	305	4.250	3.58	304.7
V-6	351	4.562	3.58	351.2
V-6	401	4.875	3.58	400.9
V-12	702	4.562	3.58	702.4

d

702

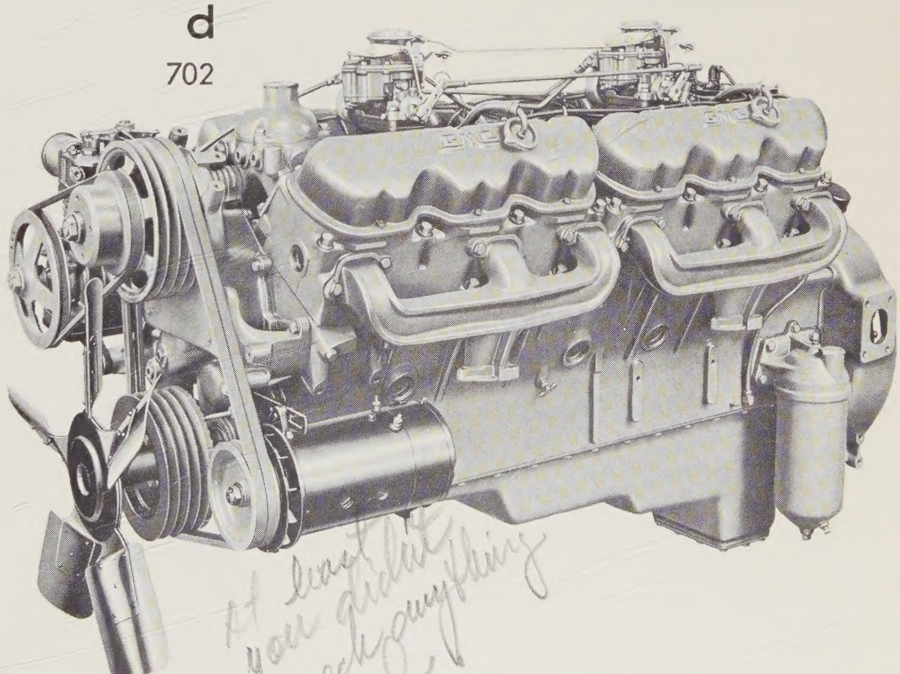
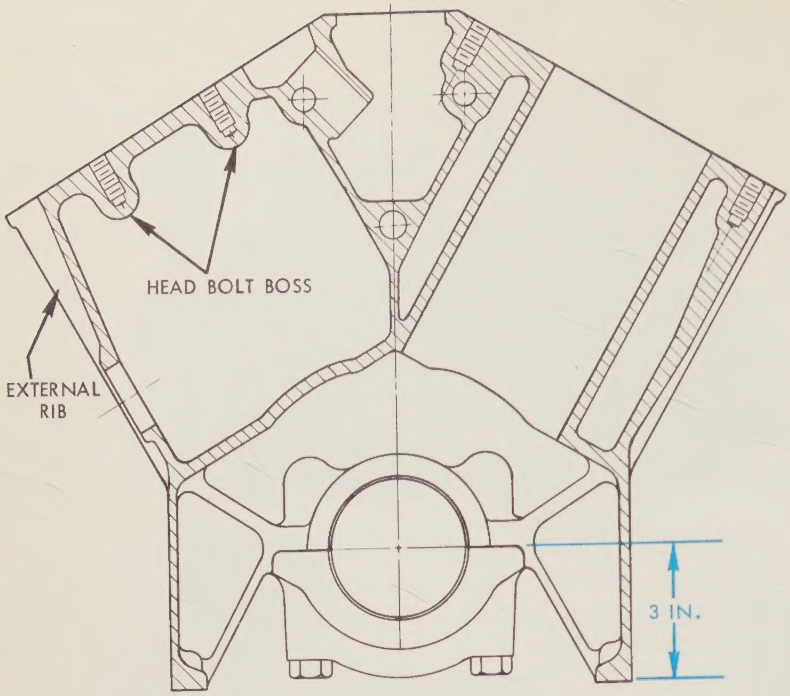


Fig. 1—Four engine models comprise the new series of V-6 and V-12 engines developed by the GMC Truck and Coach Division. The three V-6 engines (a,b,c) have displacements ranging from 304.7 to 400.9 cu in., horsepower ratings from 150 to 205, and torque outputs from 260 to 377 ft-lb. The V-12 engine (d), called the Twin Six, is rated at 275 hp and has a gross torque output of 630 ft-lb. The engines have an "over square" design, meaning that the bore dimension of each is greater than its stroke, as indicated in the table. A significant characteristic of the engines is their ability to develop maximum torque output at moderate engine speeds. For example, the 401 model engine develops maximum torque at approximately 1,400 rpm, as compared to approximately 2,500 rpm for V-8 engines.

At least you didn't wreck anything good



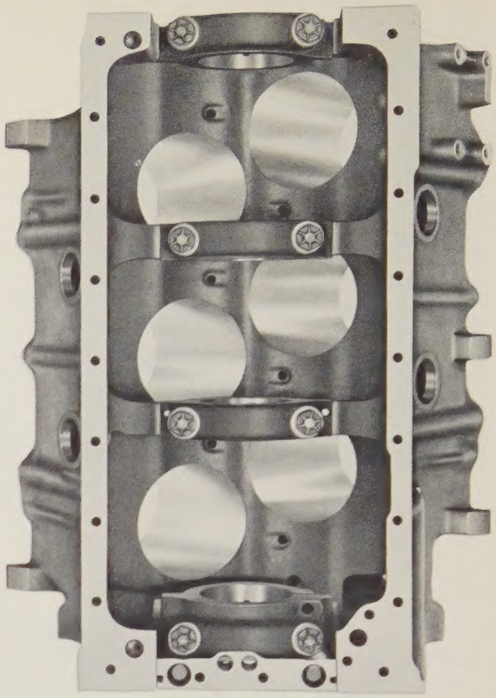


Fig. 2—To give the cylinder blocks for the V-6 and V-12 engines maximum rigidity, the vertical walls of the crankcase portion are extended three inches below the centerline of the crankshaft (left). Further rigidity is achieved by vertical ribs on the water jacket outer walls and reinforcing ribs in the main bearing bulkheads. The rear wall of the cylinder block is reinforced by oil passage bosses to and from the oil filter pad, by the oil pump shaft passage, and by the crankcase breather passage. There are three oil galleries drilled the length of the cylinder block. The main gallery is located within the Vee, below the camshaft; the other two, also within the Vee, intersect the valve lifter bores.

Shown at the right is a bottom view of the cylinder block construction which illustrates the rigid bearing caps and also the offset arrangement of the cylinder banks.

also serve to force the charge into the combustion chamber proper as the piston travels upward on the compression stroke. This creates a desirable turbulence to promote fast flame propagation. Quench areas also are known as *squish* areas when designed to promote fast flame propagation.

Actual tests indicated this reasoning to be correct. The second chamber design evaluated had dual quench areas and showed a tendency toward random knock. This tendency was eliminated by removal of the quench area under the spark plug. This resulted in the third and final design evaluated (Fig. 4c). This design moves the mass of the combustion volume toward the spark plug and consequently provides a more favorable relationship of flame volume increase versus flame travel.

To machine the combustion chambers, a wide angle traversing cutter, inclined

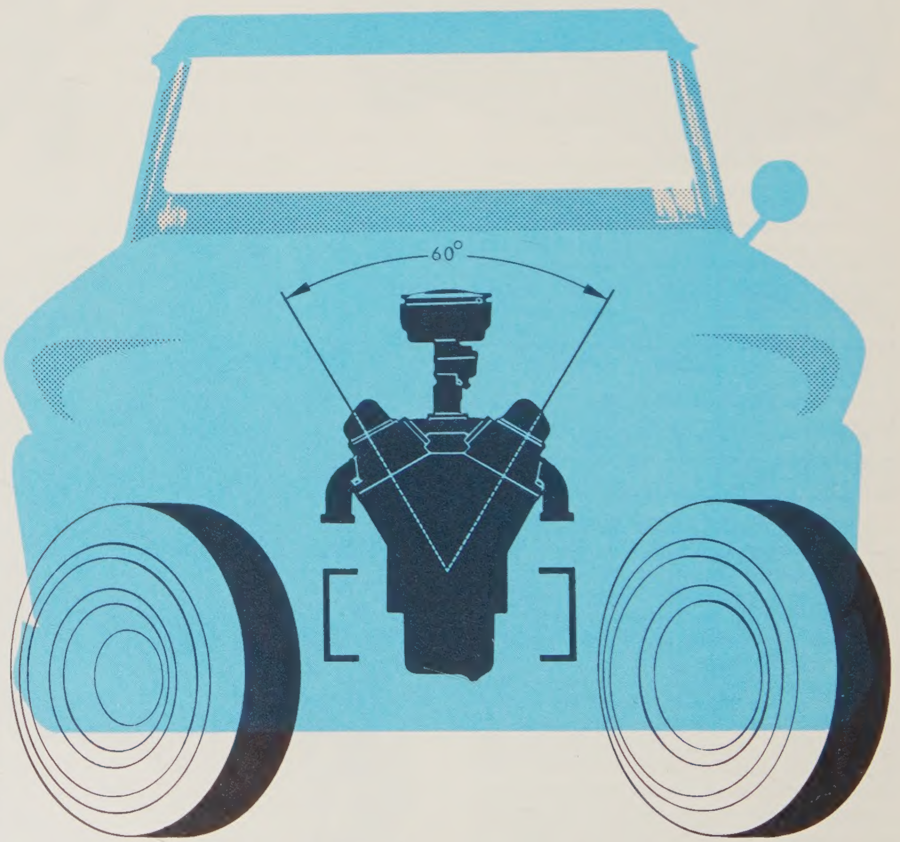


Fig. 3—The 60° cylinder block permits the design of a narrow engine that fits between the frame rails and does not interfere with the front wheel or steering mechanisms. The height of the block is such that even in the smallest truck, the air cleaner can be mounted directly on the carburetor and still obtain adequate air cleaner-to-hood clearance.

at six degrees, is used along with two composite plunge cutters on the valve centers. The plunge cutters machine their respective portions of the chamber in conjunction with the machining of the port throats.

Valve Mechanism Designed for Durability and Ease of Maintenance

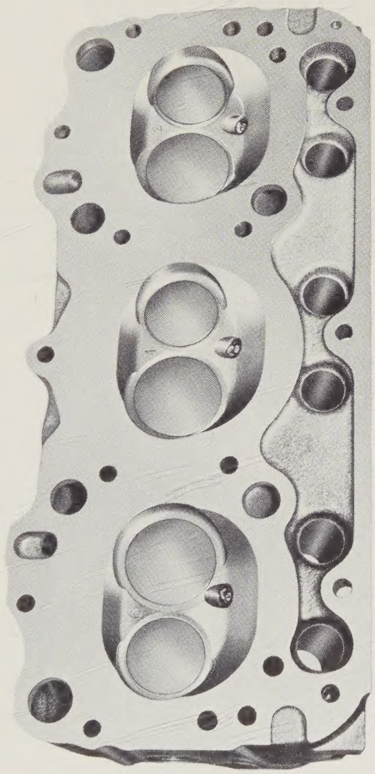
Three different arrangements are used to drive the high-mounted camshaft located within the Vee of the engine. A silent chain with matching sprockets is used on the 305 engine in light duty trucks, a roller chain and sprockets on the 305 and 351 engines in medium duty trucks, and a three-gear drive on the 401 and 702 engines in heavy duty trucks (Fig. 5). The three V-6 engine models use

Valve mechanism durability is increased by generous lubrication of camshaft and valve lifters immediately upon starting the engine. To provide this lubrication, the cylinder block oil drain holes within the Vee constitute standpipes. Oil does not drain until the level is sufficiently high to cause dipping of the cam lobes as the camshaft rotates (Fig. 6). The oil level is maintained by overflow oil from the rocker arms and from oil galleries which communicate with each valve lifter.

For ease of maintenance, valve lifters may be replaced without removing the cylinder heads or the intake manifold. The lifters may be removed or reassembled through access holes in the cylinder heads. Valve clearance adjustment also is simplified. Valve lash is adjusted by

common multi-cylinder Vee-type engines. Because of the geometry of the crankshaft, and the primary inertia forces acting on it, these forces produce an unbalanced primary inertia rocking couple. Also similar to a 90° V-8 engine two-plane crankshaft, the rotating masses of the crankpins and connecting rod big ends of the V-6 engine produce an unbalanced rotating centrifugal rocking couple. The resultant unbalanced rocking couple due to the unbalanced primary and centrifugal rocking couples are completely neutralized by suitable crankshaft counterweights.

The vertical and horizontal components of the secondary inertia forces of the V-6 engine with a 60° angle between cylinder banks are given by the following two equations:



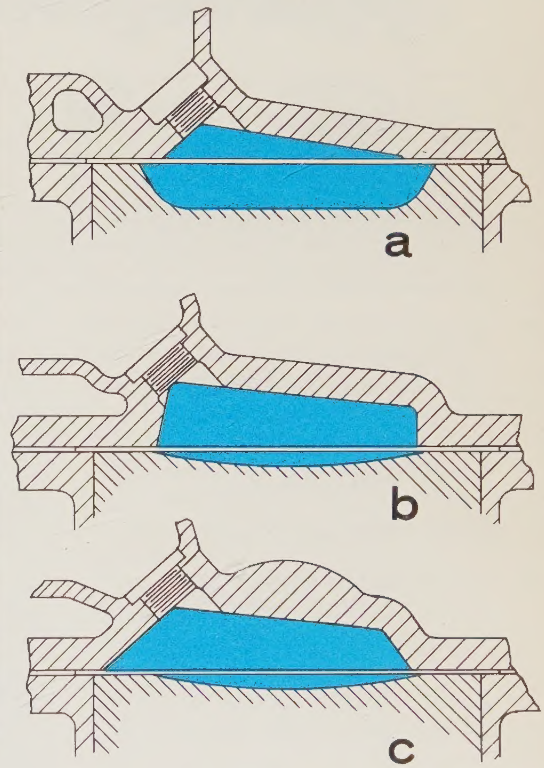


Fig. 4—Fully-machined combustion chambers in the cylinder head (left) increase turbulence of the fuel-air charge and assure rapid burning of the charge during the start of the power stroke. The machined chambers also provide for freer breathing and close regulation of the compression ratio. To accommodate the varied breathing requirements of the four engine models, two different size combustion chambers and cylinder heads are used—one for the 305 engine and the second for the 351, 401 and 702 engines.

Three combustion chamber designs were evaluated before a final design was achieved (right). The first design evaluated was a wedge-type chamber (a) which had additional combustion volume provided by a relatively large concentric depression in the top of the piston. Because of the shallow chamber, there was the possibility of the valves striking the piston should false valve motion occur. Since valve head clearance notches in the piston top face were undesirable, the wedge type design was discarded and a second type of chamber design was evaluated (b). This chamber shape, known as an inverted bath tub tilted at an angle of six degrees, had a deeper chamber with only a shallow spherical sector depression in the top of the piston. This chamber produced adequate breathing capacity through the valves. Developmental tests indicated, however, that better results could be obtained if the large quench area on the spark plug side of the chamber were eliminated. Elimination of the quench area resulted in the third, and final, design (c). This combustion chamber design moves the mass of the combustion volume toward the spark plug and provides a favorable relationship of flame volume increase versus flame travel.

Identical camshafts. The high position of the camshaft in the engine makes it possible to provide a tachometer drive from the rear of the camshaft, above the flywheel housing.

Hydraulic valve lifters are not used in the V-6 engines, but are used in the V-12 engine. The operating speed of the V-12 engine is relatively low and lifter pump-up speed presents no problem.

turning a ball stud in each rocker arm. The ball stud contains self-locking threads and locks where set.

V-6 Engine Balance Analyzed

Because the V-6 engine is an unusual type, a discussion of the engine balance is in order. The V-6 engine has complete primary inertia force balance, similar to the primary inertia forces of the more

vertical component

$$= \frac{1.5\,(d)\,(W_i)\,(r^2)\,(\omega^2)\,(\sin 2\Theta)}{(g)\,(L)} \quad (1)$$

horizontal component

$$= \frac{1.5\,(d)\,(W_i)\,(r^2)\,(\omega^2)\,(\cos 2\Theta)}{(g)\,(L)} \quad (2)$$

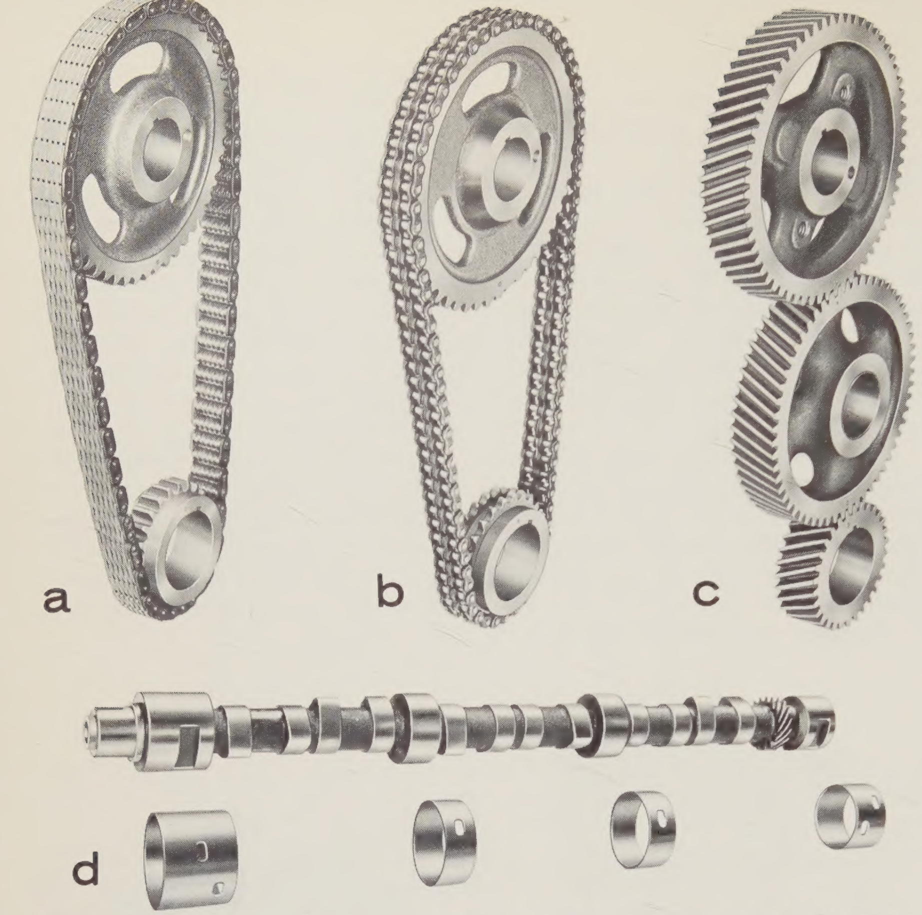


Fig. 5—Three different drive arrangements are used to drive the camshaft: a silent chain with matching sprockets (a) for the 305 engine in light duty trucks, a roller chain (b) for the 305 and 351 engines in medium duty trucks, and a three gear drive unit (c) for the 401 and 702 engines used in heavy duty trucks. The three V-6 engines use identical camshafts (d) which are supported by four equally spaced journals. The camshaft in the V-12 engine uses seven journals.

where

d = cylinder spacing (in.)

W_i = reciprocating weight (lb)

r = crank radius (in.)

Θ = crank angle (degrees)

ω = angular velocity of the crankshaft (radians per sec)

g = acceleration due to gravity (in. per sec^2)

L = connecting rod length (in.).

Since the vertical component, equation (1), is a sine function of the crank angle and the horizontal component, equation (2), is a cosine function, one component is maximum when the other is zero. The resultant of the two components, therefore, describes a circle. A solution of equations (1) and (2) shows there is a couple rotating in a direction opposite to that of the crankshaft and at twice crankshaft speed. This secondary couple can be balanced by a shaft rotating at twice crankshaft speed and containing properly phased counterweights.

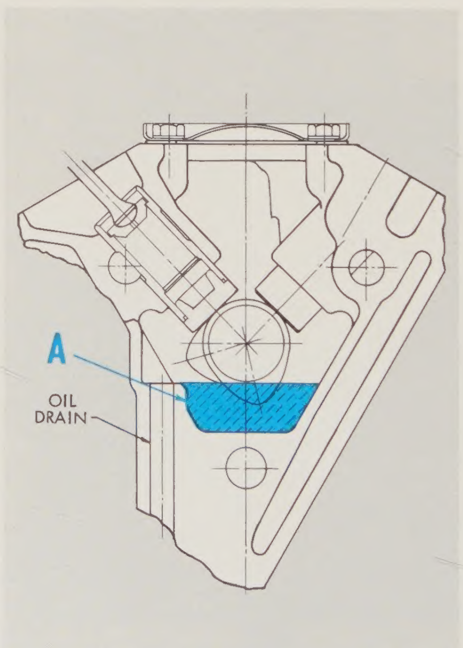


Fig. 6—Generous lubrication of valve lifters immediately upon starting the engine is provided by camshaft lobe dipping. Once the engine is started, most of the oil is splashed out of the pocket *A*.

The unbalanced secondary rocking couple can be expressed by an equivalent centrifugal couple rotating at twice crankshaft speed as follows:

$$(WR)\ (D) = \frac{1.5\ (d)\ (W_i)\ (r^2)}{4L}\ (\text{in.}^2\text{-lb})$$

where

WR = static moment of each secondary counterweight

D = spacing between secondary counterweights.

The counterweights are phased at each end of the balance shaft to produce, at twice crankshaft speed, an equivalent centrifugal couple which neutralizes the unbalanced secondary rocking couple. Because the order of magnitude of the secondary rocking couple is so small, a secondary balance shaft has not been found necessary in the GMC V-6 engines.

The linear movement of the V-6 engine, due to the unbalanced secondary rocking couple, can be expressed by the following equation:

engine linear movement

$$= \frac{(K_{sc})\ (W_i)\ (r^2)\ (l)}{4(L)\ (J)}\ (\text{in.}) \qquad (3)$$

where

K_{sc} = ratio between secondary rocking couple and the single cylinder secondary inertia force

l = span between engine supports (in.)

J = polar moment of inertia of the engine (in.^{2}-lb).

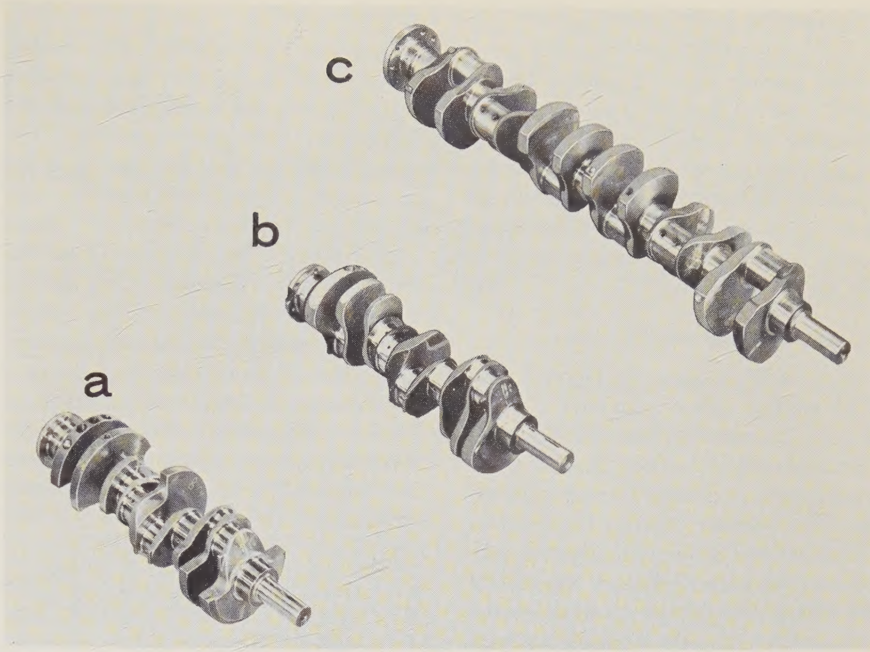
Equation (3) gives the linear movement of an engine floating freely in space and subjected to the unbalanced secondary inertia forces.

A solution of equation (3) for the GMC V-6 engine gave a linear movement of 0.0015 in. This small amount of engine movement is absorbed by rubber engine mounts. The linear movement of the engine was confirmed experimentally by mounting and running the V-6 engine on large air bellows having practically zero spring rate.

Cast and Forged Crankshafts Have Identical Machined Dimensions

To obtain equal firing intervals, the V-6 engine has six individually spaced crankpins on the crankshaft. Crankpins No. 1 and No. 2 are arranged so there is a 60° angle, measured in the direction of rotation, between the pins. These crankpins are connected by a crank cheek, sometimes referred to as a flying web, and overlap each other through the cheek. Crankpins No. 3 and No. 4 and No. 5 and No. 6 are arranged in a similar manner. There are four main journals on the V-6 engine crankshaft—at the front and rear and between pairs of crankpins.

The production 305 engine has a cast ArmaSteel* crankshaft. The heavier duty 351, 401, and 702 engines have forged steel crankshafts to provide for induction hardened main and crankpin journals. The cast and forged crankshafts for the V-6 engines have identical machined dimensions (Fig. 7).



CRANKSHAFT STROKE	MAIN JOURNAL FILLETS	CRANKPIN FILLETS	MAIN JOURNAL DIAMETER	CRANKPIN DIAMETER	CRANK CHEEK THICKNESS	REAR WEB THICKNESS
3.58 IN.	0.102 IN.	0.164 IN.	3.125 IN.	2.812 IN.	0.936 IN.	1.402 IN.

Fig. 7—The 305 V-6 engine uses a cast ArmaSteel crankshaft (a). Forged steel crankshafts are used in the 351 and 401 V-6 engines (b) and in the 702 V-12 engine (c). The forged and cast crankshafts for the V-6 engines have identical machined dimensions, as listed in the table.

Developmental Program Provided Crankshaft of Infinite Stress Life

The development of the crankshaft for the V-6 engine was one of the most interesting phases of the engine design program. The unusual configuration of the V-6 engine crankshaft required the following developmental program to provide a crankshaft of infinite stress life:

(a) Fatigue test crankshaft sections having varying crankpin diameters, fillets, and web thicknesses (Fig. 8). This work was carried out by the GM Research Laboratories

(b) Study crankpin overlap sections and calculate section moduli to determine extent of changes possible by increasing journal diameters, fillets, and web thicknesses

(c) Measure actual bending amplitude at crankshaft front end during operation to determine effect of crankshaft pulley mass on bending amplitude

(d) Make static bending and torsional tests to determine stress versus amplitude of twist and bend on the crankshaft

(e) Investigate the use of rolled, undercut, or peened fillets to provide ample fatigue strength

(f) Develop a forged crankshaft for the V-6 engine

(g) Investigate other engine component changes that would ensure infinite crankshaft fatigue life.

Original durability tests performed on the V-6 engine were run with the engine flywheel coupled to a dynamometer in the usual manner. However, on the largest V-6 engine—the 401—the durability tests did not represent the equivalent inertia of the flywheel and the 13-in. standard or 14-in. optional clutches that would be used on production vehicles. The equivalent inertia was added and further tests conducted.

A measurement of the bending amplitude of the crankshaft was first made. This was done with strain gage displacement bars mounted on the flywheel housing. The bars rubbed on an extension shaft fastened to the rear flange of the crankshaft. Measurements of the bending amplitude were fed into an oscilloscope and then plotted automatically on a polar diagram showing movement of the crankshaft while the engine was running. Next, crankshaft bending fatigue tests were run to determine effects of fillet radii, journal diameter, and web thickness on fatigue strength. Static bending tests were then performed on the crankshaft rear cheek.

These tests showed that there was resonant bending at the rear of the crankshaft which occurred at an engine speed considerably above the governed speed when either a 13-in. or 14-in. clutch was used. Resonant bending occurred at much higher speeds when an 11-in. or 12-in. clutch was used.

A plot of the bearing forces acting on the No. 5 and No. 6 crankpins and the No. 4 journal showed the exciting force to be caused by the firing order and crankshaft configuration, which produced a three-times-per-revolution excitation.

To prove the fatigue life of the crankshaft, a durability test was conducted by running the engine for nearly 1,000 hours at the resonant bending speed. No failure occurred.

*ArmaSteel is a trademark of General Motors Corporation denoting a graphitic, steel-like material consisting of a matrix of sorbitic pearlite and spheroidized cementite in which small nodules of carbon are imbedded.

Cooling System Provides High Velocity, High Capacity Flow

The greater valve durability of the GMC V-6 and V-12 engines is due primarily to a high velocity flow of engine coolant through the cylinder heads. Coolant flow is provided during both warm-up (thermostat closed) and normal operation (thermostat open) of the engine.

Coolant Flow Path

The cooling system of the V-6 and V-12 engines differs from that of other engines because of the amount and principal path of the flow. Flow from the water pump is divided equally between the two cylinder banks. The coolant circulates around the full height of each cylinder barrel and then to the rear of the block. The major portion of the coolant flows from the block to the heads at the rear cylinder in each bank. From there, coolant is directed forward in both heads to the water outlet manifold.

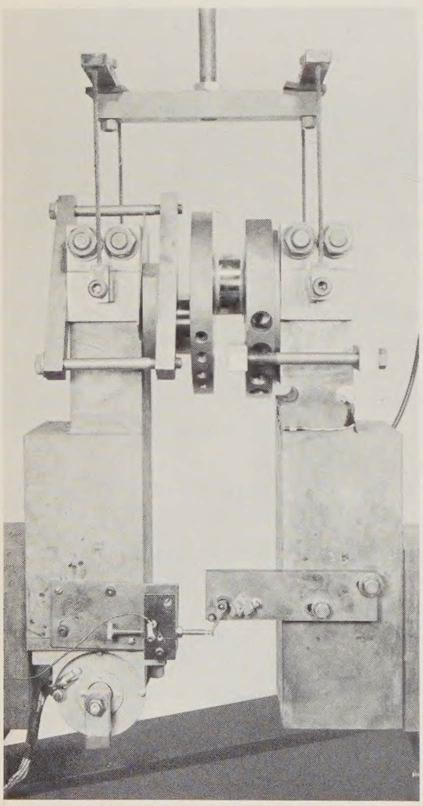


Fig. 8—Shown here is the fixture used to perform a bending fatigue test on a crankshaft section. Two pendulum weights were fastened to the crankshaft section and the whole mass vibrated by means of an electric motor with a rotating eccentric weight. Since the amplitude of vibration could be varied, the stress in the journal fillets could be increased or decreased with this test fixture.

Permanent By-Pass

Both the V-6 and V-12 engines contain a permanent by-pass from the water manifold, on the engine side of the thermostat, to the water pump inlet. The water outlet to the radiator and the permanent by-pass was sized so that approximately 50 per cent of the coolant flows through the by-pass when the thermostats are fully open. Only enough coolant for proper radiator heat dissipation is circulated through the radiator. The return of coolant, through the permanent by-pass, from the water manifold to the water pump inlet appreciably increases water pump capacity and total flow through the engine. An additional advantage is the high rate of coolant flow through the engine during the warm-up period, which results in even engine temperature distribution under all operating conditions.

During development of the cooling system it was found that a greater total coolant flow resulted with the addition of the permanent by-pass from the water manifold to the pump inlet cavity in the engine front cover (Fig. 9).

Water Pumps

Two water pumps of different capacity are used. The smaller pump, used in the 305 engine, circulates 130 gpm through the engine at an engine speed of 3,600 rpm when the thermostat is open and 82 gpm when the thermostat is closed. The larger pump, used in some 305 engines and in all 351, 401, and 702 engines, circulates 180 gpm through the engine at an engine speed of 3,600 rpm when the thermostats are open and 148 gpm when the thermostats are closed.

One thermostat is used in most 305 engines and two thermostats in some 305 and in all 351 and 401 engines. Three thermostats are used in the 702 engine.

A bench set-up was used for conducting initial tests on the water pumps to investigate pump capacity and distribution. Cooling system tests were then made to determine water distribution inside the engine. These tests consisted of measuring coolant temperatures in the cylinder block and cylinder head. Visual observation of flow conditions in the cylinder head was made possible by replacing the top wall of the head with a transparent plastic sheet. The tests resulted in a relocation of water transfer holes in the cylinder block and cylinder head and the addition of baffles within the cylinder head casting. The final design was checked using thermocouples installed in the cylinder head casting at critical areas only 0.10 in. from the surface being investigated.

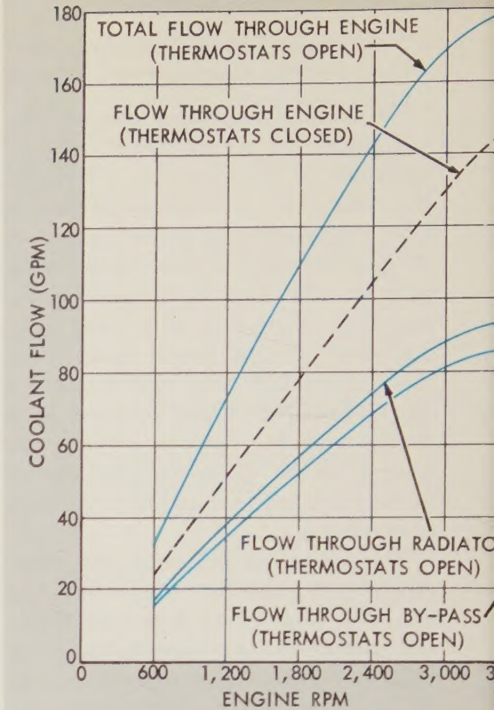


Fig. 9—This curve shows the amount of coolant flow through the engine under conditions of engine warm-up (thermostats closed) and normal operation (thermostats open). The total flow through the engine, with thermostats open, is the sum of the flow through the radiator and the flow through the permanent by-pass.

Summary

Development of the V-6 and V-12 engines by GMC engineers has yielded a series of engines designed specifically to meet the needs of the trucking industry. In addition to meeting all light duty to heavy duty truck powerplant requirements, the engines also provide economic benefits to operators through such design features as maximum durability, ease of maintenance, and parts interchangeability within the various engine models. With proper application and maintenance, the engines have a potential of 200,000 miles of continuous operation without major overhaul.

Bibliography

1. Locklin, J. G., and Fleck, F. C., "Laboratory Testing Verifies Design of Lightweight Fabricated Frame for Highway Tractors," *General Motors Engineering Journal*, Vol. 6, No. 4 (October-November-December 1959), pp. 14-20.

Radioisotope Techniques Used to Measure Wall Thickness of Hollow Turbine Blades and Vanes

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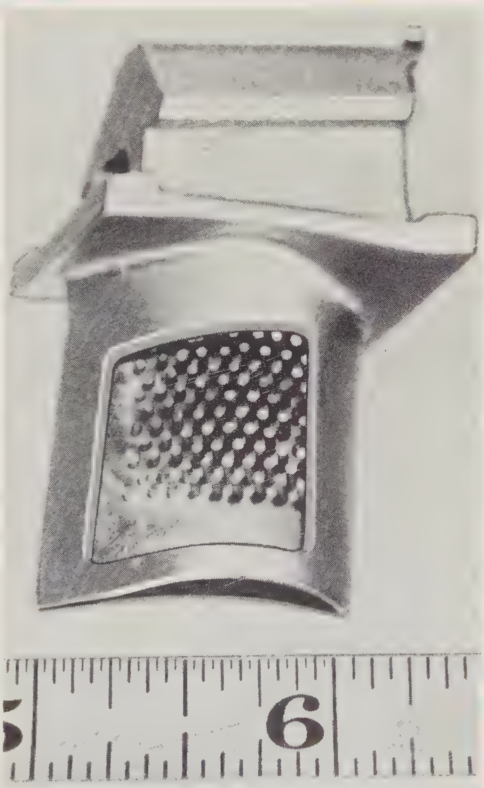
Technique based on amount of radiation transmitted through the walls

The industrial use of radioisotopes as an engineering tool is constantly increasing as more radioisotopes become available, more basic data relating to the industrial use of nuclear energy are gathered, and more experience is gained in learning how to apply isotopes successfully to developmental and manufacturing situations. A recent example of one more industrial use of radioisotopes occurred as a result of a need by Allison Division engineers to measure airfoil wall thicknesses of hollow turbine blades and vanes. Attempts to measure the airfoil thicknesses by conventional nondestructive methods were unsuccessful due to the size and shape of the specimens and the presence of internal supporting structures in both the blades and vanes. The problem was then presented to the Isotope Laboratory of the GM Research Laboratories to see if radioisotope techniques could be applied to obtain the required thickness information. An isotope technique was developed in which specimens were filled with a source of samarium-153 dissolved in a hydrochloric acid solution and the thickness determined by measuring the radiation transmission through the airfoil walls. The thicknesses measured by the isotope method were, in most regions, within 3 to 10 per cent of optical measurements made on sectioned specimens.

A NEW design for first stage turbine blades and turbine vanes was recently undertaken by the Allison Division to increase the horsepower of an experimental T56 turbo-prop engine. The new design featured hollow blades and vanes with a number of internal supports so that coolant gases could be forced through the airfoils (Fig. 1). The blades and vanes were constructed by casting GMR-235, a high temperature nickel base alloy[1], into a mold having a ceramic core. It was suspected that the core frequently shifted during the casting process, resulting in variations in airfoil wall thickness. Measurements of the wall thickness, as cast, were necessary because abnormally thin or thick sections would have a tendency to rupture or otherwise fail during the extreme operating conditions of the engine.

Attempts to measure the wall thicknesses by conventional nondestructive methods were unsuccessful due to the geometry and internal structure of the blades and vanes. The problem of measuring the airfoil wall thicknesses was then presented to the General Motors Research Isotope Laboratory to see if nuclear techniques could be applied. After preliminary experimentation, it was decided that a liquid radioisotope technique could be applied which would afford the versatility necessary in the event of possible design changes in the blades and vanes. This technique would also be fairly rapid, operationally simple, and sensitive to airfoil wall thickness changes of a thousandth of an inch in the range of interest.



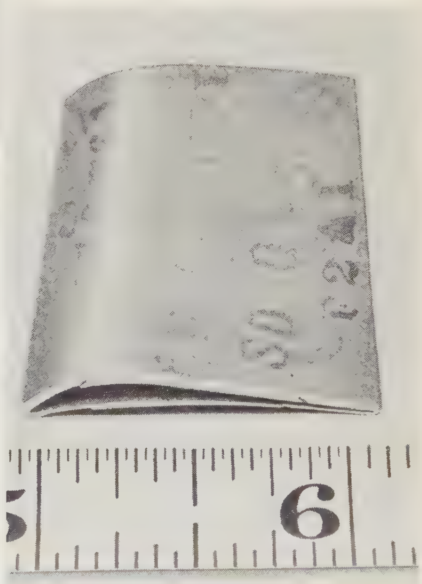


Fig. 1—A new design of first stage turbine blades and turbine vanes for the experimental Allison T56 turbo-prop engine called for hollow sections with supporting posts between the walls to permit coolant gases to be forced through the airfoils. Shown at the left is a turbine blade with a portion of the convex surface removed to expose the internal supports. At the right is a turbine vane which has the same internal structure as the blade.

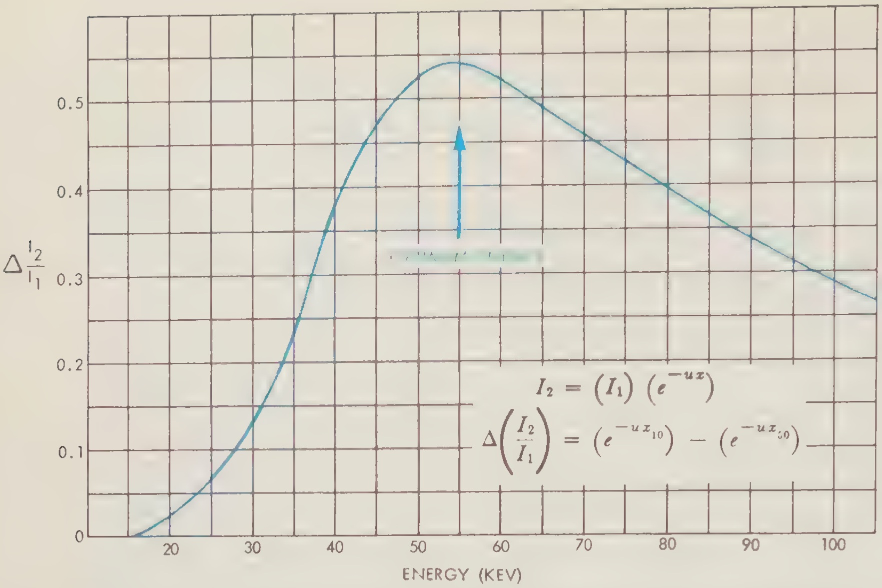


Fig. 2—This is an optimum isotope radiation energy curve developed to determine the optimum monochromatic energy required for thickness determinations of the GMR-235 alloy used to cast the turbine blades and vanes. The thickness determinations were to be made in a range from 0.010 in. to 0.050 in. The optimum energy required was that at which a maximum difference occurred between the intensity ratios I_2/I_1 at the thickness limits of the alloy. The optimum energy required was found to be 55 kev.

How the Proper Isotope Was Chosen

When selecting a radioisotope for a particular application, the following factors must be considered:

- Type, abundance, and energy of the radiation
- The rate of decay, or half-life, of the isotope
- The availability and cost of the isotope
- The chemical and physical properties of the isotope.

The energy of the radiation is of prime importance in thickness measurements. In the case of the blade and vane thickness measurements, a gamma energy was required such that a small change in the airfoil thickness would cause a detectable change in radiation intensity.

To determine the radiation energy required, the absorption rule for a homogeneous beam was applied. This rule is expressed in equation form as

$$I_2 = (I_1)\,(e^{-\mu x}) \qquad (1)$$

where

I_2 = intensity of the radiation transmitted through the material

I_1 = intensity of the radiation incident on the material

μ = linear absorption coefficient of the material for a particular energy (cm^{-1})

x = thickness of the absorber (cm).

The optimum energy of the radiation would be that at which a maximum difference occurred between the intensity ratios I_2/I_1 at the thickness limits of the GMR-235 alloy. This intensity ratio difference may be expressed as

$$\Delta\left(\frac{I_2}{I_1}\right) = \left(\frac{I_2}{I_1}\right)_{x_{10}} - \left(\frac{I_2}{I_1}\right)_{x_{50}}$$

or,

$$\Delta\left(\frac{I_2}{I_1}\right) = \left(e^{-\mu x_{10}}\right) - \left(e^{-\mu x_{50}}\right) \qquad (2)$$

where

x_{10} = 0.010 in. (0.025 cm) of GMR-235 alloy

x_{50} = 0.050 in. (0.125 cm) of GMR-235 alloy.

The values for x_{10} and x_{50} in equation (2) were chosen to coincide with the range of 0.010 in. to 0.050 in. which would be encountered in the blade and vane airfoil thickness measurements.

Before the left-hand side of equation (2) could be determined, a value for the linear absorption coefficient μ was required. Since μ values as a function of energy for GMR-235 were unknown, μ values for copper were used instead. These coefficients would serve as a good approximation, since the density and atomic number of copper and GMR-235 are about equal.

The μ values for copper were obtained from the literature[2]. These values were then substituted into equation (2) and a value for $\Delta\ (I_2/I_1)$ determined. This value was then plotted as a function of energy. The optimum monochromatic energy was found to be 55 kev for thickness determinations of GMR-235 in the 0.010-in. to 0.050-in. range (Fig. 2).

Reference to a Chart of the Nuclides[3] showed several isotopes that might be used for the thickness measurements, including Tm-170, Sm-145, Sm-153, Pd-

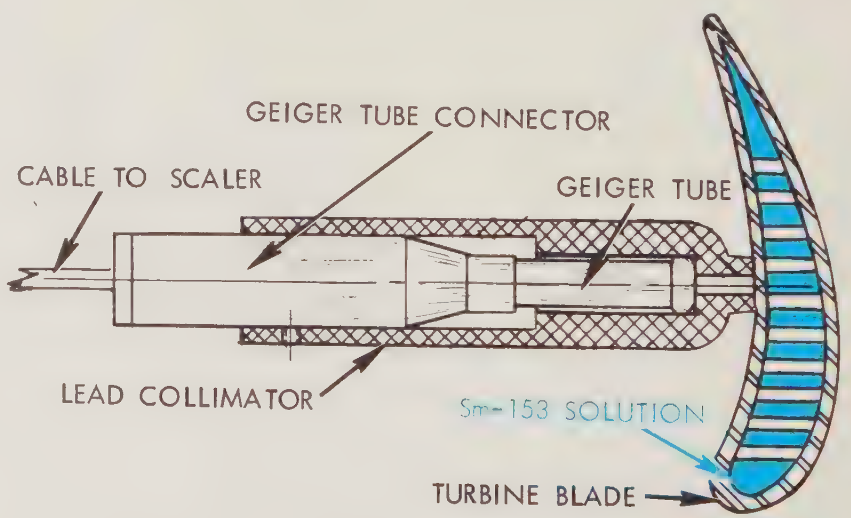


Fig. 3—Shown here is a cut-away view of the detector assembly used to determine absorption rates. The detector assembly was used in conjunction with a special fixture (Fig. 5) which assured that the detector would be properly positioned with respect to the measurement location on each turbine blade or vane.

109, and Cd-109. The isotope chosen was Sm-153. It was selected for the following reasons: (a) its relatively short half-life of 47 hours would be desirable for the thickness measurement work and would also be advantageous in case of spills or other decontamination problems, (b) it could be supplied by the Oak Ridge National Laboratory on a weekly schedule and at a reasonable cost, and (c) the irradiated target, Sm_2O_3, would be readily soluble in one molar hydrochloric acid.

The gamma emissions of radioactive Sm-153 have energies of 106 kev and 70 kev with a relative abundance of approximately 4.25 to 1, respectively. This gives an apparent effective energy of about 104 kev. Referring to Fig. 2, it is evident that this effective energy would not be the most efficient for determining thicknesses. However, because of the counting geometry, scattering processes, and variation of detector efficiency with different energies, it was felt that the *actual* effective energy of Sm-153 might be somewhat lower.

Absorption studies were made using Sm-153 and different thicknesses of the GMR-235 alloy. Data from these studies made it possible to solve equation (1) for the linear absorption coefficient μ. The effective linear absorption coefficient μ was calculated to be approximately equal to 13. The mass absorption coefficient of GMR-235 was then equal to

$$\frac{\mu}{\rho} = \frac{13.0}{8.1} = 1.61$$

where

ρ = density of the GMR-235 alloy.

From published data on copper, this mass absorption coefficient corresponds to 60 kev and is close to the ideal energy of 55 kev.

The next step was to select a detector to determine the absorption rates. An Anton No. 222 Geiger-Mueller tube was chosen because it is one of the smallest Geiger tubes commercially available (Fig. 3). A lead collimator was designed to house the tube and to collimate the beam of radiation entering the window of the tube. The collimator hole was ⅛ in. in diameter. This diameter was chosen so that sufficient count rates could be obtained on an assorted scaler with minimum counting times at the positions on

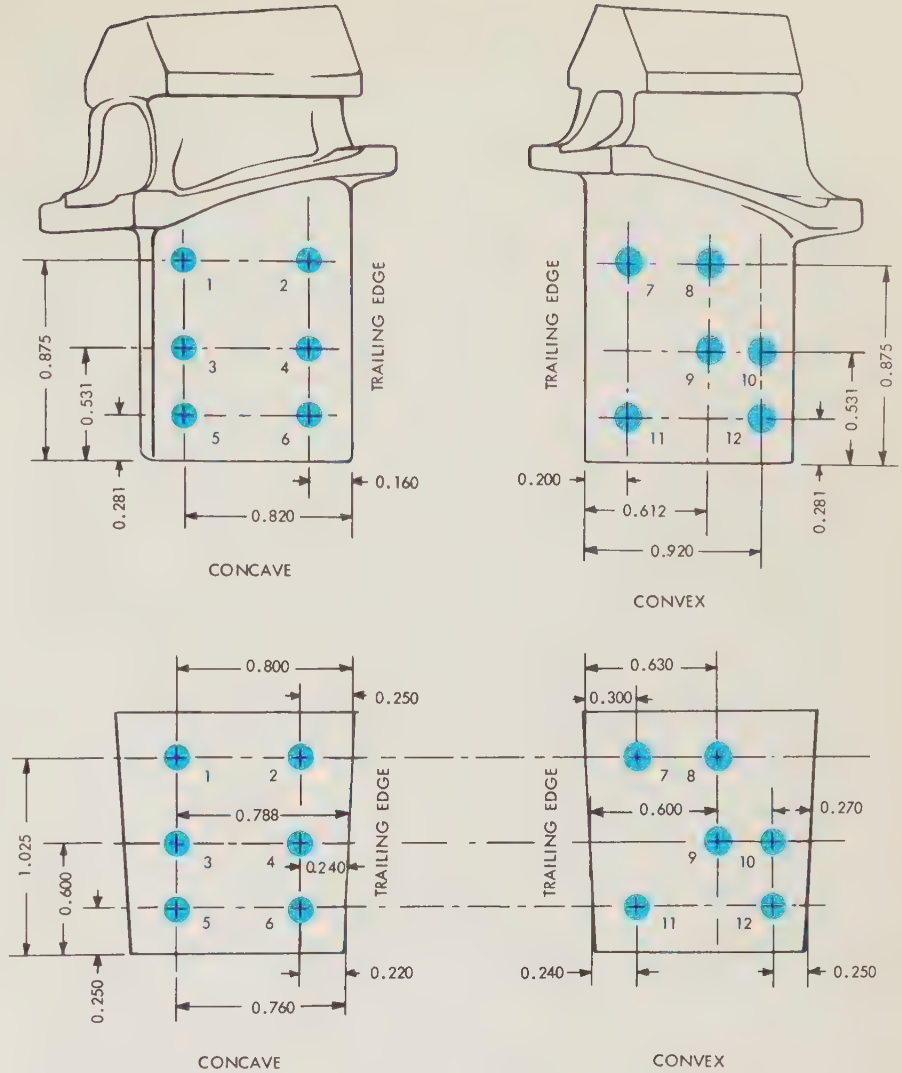


Fig. 4—Thickness measurements of the airfoil walls on both the turbine blades (top) and turbine vanes (bottom) were required at 12 locations—six on each concave side and six on each convex side.

the airfoils where the thickness was to be measured.

Thickness Measured at Twelve Locations

The thickness of each blade and vane was measured at 12 locations, six on the concave side and six on the convex side (Fig. 4). An inspection fixture was designed and constructed to insure exact positioning of the detectors with respect to the measurement location on each turbine blade or vane (Fig. 5). The detector assemblies were positioned at the six locations on either the convex or concave side of a blade or vane specimen by means of locating pins and spacer blocks. The inspection fixture was mounted in a glovebox while thickness measurements were made (Fig. 6).

Samarium activity was purchased from the Oak Ridge National Laboratory as an irradiated target consisting of 0.03 gm of $Sm_2{}^{153}O_3$ contained in an aluminum tube. The total induced activity was approximately 50 millicuries. Two milliliters of one molar hydrochloric acid were added to the tube to dissolve the samarium oxide. This solution was brought to volume with one molar hydrochloric acid containing 0.001 per cent poly-oxyethylene sorbitan monolaurate (Tween 20), which served as an effective wetting agent and prevented formation of air bubbles when filling the blade or vane specimen. Preliminary experiments indicated that a five milliliter volumetric flask gave the desired concentration for a sufficient count rate. The concentration of the Sm-153 was, therefore, about 10 mc per ml. The samarium solution was injected into the blade or vane with a hypodermic syringe having a 3-in., 22-gage needle. Before injection, one end of the specimen was sealed with double-faced adhesive tape.

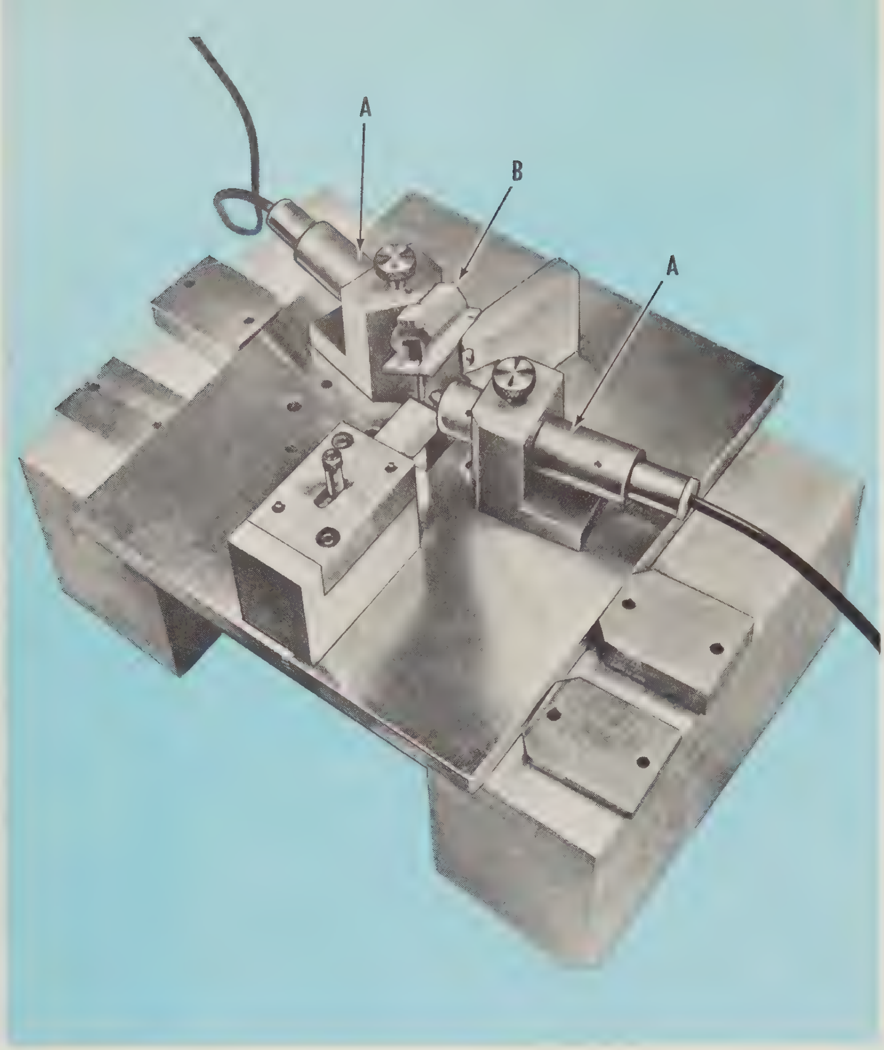


Fig. 5—A special fixture was designed and constructed to assure that the detectors, used to determine the count rates, were positioned properly with respect to the measurement location on each turbine blade and vane. The detector assemblies *A* were positioned at the six locations on either the convex or concave side of a blade *B* or vane by means of locating pins and spacer blocks. Examination of a blade or vane, using both detectors simultaneously, was completed in seven to eight minutes.

Counting times varied with the specific activity of the Sm-153. However, all data presented in this paper are based on a counting time of one minute.

Thickness Read from a Transmission Curve

The fundamental principle underlying the airfoil thickness determinations was the relationship of the count rate to the thickness.

The usual method for determining thickness involves a constant activity source. The transmission through known thicknesses of material is measured using this constant source. A standard curve is then plotted and unknown thicknesses are determined from the curve.

For the airfoil thickness determinations, however, such a plot of thickness versus count rate of standard blades would result in 12 transmission curves, one for each measurement location, and would extend over the limited thickness range of each of the locations. The reason for this is that the source strength would not be constant at the various locations where measurements were required due to the shape of the specimens. It was found easier and more expedient, therefore, to use what was termed a primary transmission curve. The count rates of the standards were then related to this curve (Fig. 7).

The standards used in these studies were blades or vanes chosen at random from a particular group of specimens being processed. Following decontamination, these specimens were sectioned with a grinding wheel and the true measurement determined at the point in question with a 20X microscope and filar eyepiece.

Since the radiation (Sm-153 activity) had the same quality in all cases, although of varying quantity, and since the absorbing material was constant, all of the count rate curves (Fig. 7) were parallel. Each curve could be related to the primary transmission curve for each measurement position by a constant factor K defined as

$$K = \frac{C_{std}}{c_{std}} \tag{3}$$

where

C_{std} = count rate given by the primary transmission curve for a known thickness of standard blade

c_{std} = measured count rate through the same known thickness of standard blade.

Twelve K factors were computed, one for each of the twelve positions at which measurements were to be taken on each specimen.

For a particular position on an unknown, the K factor was computed as

$$K = \frac{C_x}{c_x} \tag{4}$$

where

C_x = count rate given by primary transmission curve for unknown thickness x

c_x = measured count rate through the unknown thickness x.

After obtaining the count rate c_x at a particular position of an unknown, the thickness was found by solving equation (4) for C_x and then locating the value for C_x on the primary transmission curve. The abscissa of this point was the unknown thickness x.

Because of the inherent difficulty in aligning the collimator exactly perpendicular to the irregular surfaces being measured it was important to know if this alignment difficulty would cause serious errors in thickness determinations. The use of the count rate ratios and primary transmission curve were especially advantageous in this respect. No special efforts were necessary in aligning the collimator exactly perpendicular with the surface being measured as long as the measurement position was constant on the standard blade or vane and all measured specimens.

Theoretically, it would have been necessary to sacrifice only one specimen to determine the K factors used in equation (3). Sectioning a number of blades and vanes, however, allowed the

K factors of each measuring point location to be determined with greater precision. Using average K factors from a number of specimens resulted in the most reliable thickness determinations. Furthermore, an occasional erratic count rate could be detected and eliminated with enough data to insure good results.

Relocating Transmission Curve Decreased the Number of Specimens Required

Although a number of specimens have to be sacrificed initially, it would be undesirable to have to section this same number of specimens each time a new supply of samarium was used. This would be both time consuming and expensive from the standpoint of attrition of valuable specimens.

To avoid the sacrifice of a large number of specimens, the position of the primary transmission curve can be changed and used with a single set of averaged K factors. The problem here is one of relocating the primary transmission curve to use a given set of K factors rather than compute a new set of K factors to use with the curve in a fixed position.

Having assumed that the inspection fixture insures that each measuring point location is the same from blade-to-blade or vane-to-vane and that the source activity is constant at each particular point, there is a family of curves (all parallel) from which the appropriate curve is chosen for any particular concentration of activity. The curve—that is, the slope at any point—once established is valid for any specimen fabricated of GMR-235 alloy measured with Sm-153. If different blade or vane designs are to be measured, new K factors must be determined. With a given design, however, only one set of K factors is necessary irrespective of the Sm-153 specific activity.

To relocate the curve, a previously counted specimen is sectioned and measured. Knowing the K factors, the count rates (ordinates) of the relocated transmission curve are computed from the relationship

$$C_p = (K_p)\ (c_p)$$

where

C_p = computed ordinates of relocated transmission curve for each optically measured position p

K_p = the K factor for each position p previously computed from the primary transmission curve (equation 3)

c_p = measured count rate at each position p.

The ordinates C_p are plotted for each thickness and the relocated curve is then drawn parallel to the primary transmission curve through these points.

Summary

A comparison between the turbine blade and vane thickness measurements obtained by the isotope method and the optical method indicates the degree of accuracy possible with the isotope method (Table I). With the exception of a few measurements along the trailing edge of the concave side, the thicknesses measured with the isotope technique in most regions were within 3 to 10 per cent of optical measurements of sectioned specimens.

With the completion of preliminary experiments at the GM Research Isotope Laboratory, the turbine blade and vane measurement operations were transferred to the new isotope laboratory at the Allison Division. There, sufficient blades and vanes were measured to supply enough specimens for engine testing.

The liquid isotope method, described in this application to airfoil wall thickness measurement, also could be applied to other applications where standard gaging procedures are not adequate. Examples might be the gaging of small, hollow extrusions and castings of intricate design. This procedure could be adapted to almost any fabricating material because of the wide variety of isotopes and associated radiation energies available. The principal criterion for the choice of specimens is that they be fairly small so that the volume of liquid used is approximately one ml. Also, the choice of the isotope must be matched with the range of material thicknesses to be measured.

Bibliography

1. Hanink, D. K., Webbere, F. J., and Boegehold, A. L., "Development of

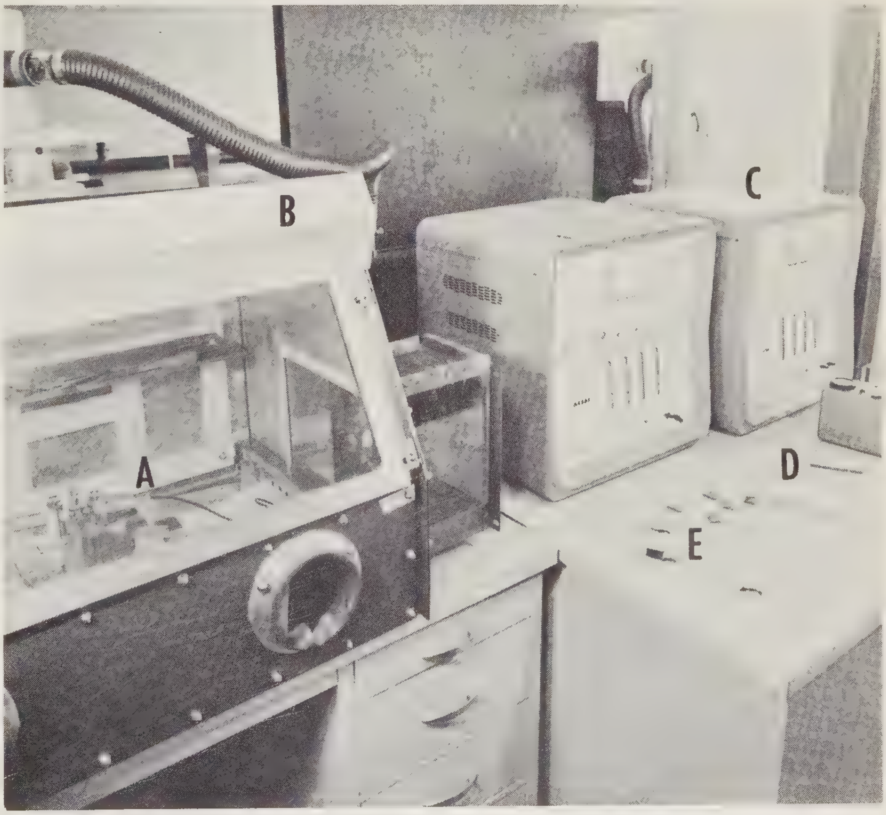


Fig. 6—Thickness measurements of the airfoil walls were made with the inspection fixture A mounted inside a glovebox B to prevent the spread of radioactive material. The blade or vane to be measured was first filled with the radioactive source in a second glovebox (not shown) adjacent to the box housing the inspection fixture. Other equipment shown in the photograph includes electronic scales (one for each detector) C, a portable survey instrument D, and blade and vane specimens E.

COMPARISON OF OPTICAL AND ISOTOPE THICKNESS MEASUREMENTS
FOR TURBINE BLADES AND TURBINE VANES
(THICKNESSES ARE GIVEN IN THOUSANDTHS OF AN INCH)

POSITION	BLADE 22			BLADE 18			BLADE 14		
	THICKNESS		PERCENT DEVIATION FROM OPTICAL	THICKNESS		PERCENT DEVIATION FROM OPTICAL	THICKNESS		PERCENT DEVIATION FROM OPTICAL
	OPTICAL	ISOTOPE		OPTICAL	ISOTOPE		OPTICAL	ISOTOPE	
1	33.4	34.0	1.8	42.2	40.0	5.5	42.3	39.8	5.9
2	14.4	15.3	6.3	24.1	24.7	2.5	24.4	23.2	4.9
3	29.2	31.0	6.2	41.2	39.0	5.3	40.6	32.5	20.6
4	12.8	14.5	13.0	23.2	21.8	6.0	22.6	20.2	10.6
5	30.8	30.3	1.6	42.0	43.5	3.6	38.4	35.8	6.8
6	9.8	12.4	26.0	20.2	20.5	1.5	21.3	17.9	15.9
7	15.4	15.4	0	19.0	18.9	0.5	17.6	17.9	1.7
8	23.2	22.6	2.6	27.6	28.8	4.0	26.1	22.9	12.2
9	26.8	27.9	4.1	31.6	32.7	3.5	29.9	30.0	0.3
10	20.1	21.3	6.0	27.4	26.3	4.0	26.4	25.8	2.3
11	20.9	21.2	1.0	22.4	23.8	6.0	19.2	18.3	4.7
12	21.0	21.2	0.9	29.7	28.5	4.0	29.4	27.8	4.7

POSITION	VANE 5			VANE 22			VANE 6		
	THICKNESS		PERCENT DEVIATION FROM OPTICAL	THICKNESS		PERCENT DEVIATION FROM OPTICAL	THICKNESS		PERCENT DEVIATION FROM OPTICAL
	OPTICAL	ISOTOPE		OPTICAL	ISOTOPE		OPTICAL	ISOTOPE	
1	41.3	41.8	1.2	47.5	46.4	2.3	40.2	38.3	4.7
2	24.9	26.8	7.7	32.3	30.0	7.1	24.7	25.3	2.4
3	41.6	42.5	2.2	46.6	45.4	2.6	40.8	40.5	0.7
4	29.0	30.5	5.2	29.8	29.0	2.7	28.1	27.0	3.9
5	43.6	43.4	0.5	51.0	51.3	0.6	43.0	40.8	5.1
6	33.9	33.8	0.3	35.9	37.3	3.9	33.2	32.8	1.2
7	37.2	36.5	1.9	37.4	38.2	2.1	41.2	38.8	5.8
8	45.4	45.4	0	49.5	49.5	0	48.6	47.7	1.8
9	42.0	44.4	5.7	48.6	47.3	2.7	45.8	45.7	0.2
10	43.5	45.0	3.5	48.0	46.4	3.3	48.5	52.3	7.3
11	29.4	30.4	3.4	36.2	33.8	6.6	28.6	27.2	4.9
12	41.0	41.7	1.7	45.0	44.4	1.3	44.3	44.3	0

Table I—This table lists thickness measurements of three blades and three vanes at the 12 measuring positions (Fig. 4) obtained by the isotope method and also by the optical method, which requires sectioning of the blade or vane. Comparison between the isotope and optical methods indicates the excellent results obtained using the Sm-153 isotope. All measurements by both methods agree closely, with the exception of a few measurements along the trailing edge of the concave side. Since the thickness of the airfoil changes rapidly in this region, a slight variation in the position at which the optical measurement is made can lead to a considerable error.

This listing points out the core shift observed in some of the specimens. For example, in blade *18* the measurements at positions *2*, *4*, and *6* indicate that the blade is thicker toward the base on the concave side while thinner toward the base on the convex side, as shown at the opposite positions *7* and *11*. Likewise, measurements at positions *1*, *3*, and *5* on vane *5* would indicate that the vane is thicker near the small open end on the leading edge of the concave side while the vane is thinner, as compared with positions *10* and *12*, on the convex side. These thickness change patterns are interpreted as core shifts.

a New Gas Turbine Super Alloy GMR-235," *S.A.E. Transactions*, Vol. 63, (1955), p. 705.

2. Kinsman, Simon, *Radiological Health Handbook* (Cincinnati, Ohio: U.S. Department of Health, Education, and Welfare) October, 1955, pp. 252-3.

3. *Chart of the Nuclides*, published by the General Electric Company, Fifth Edition, April 1956.

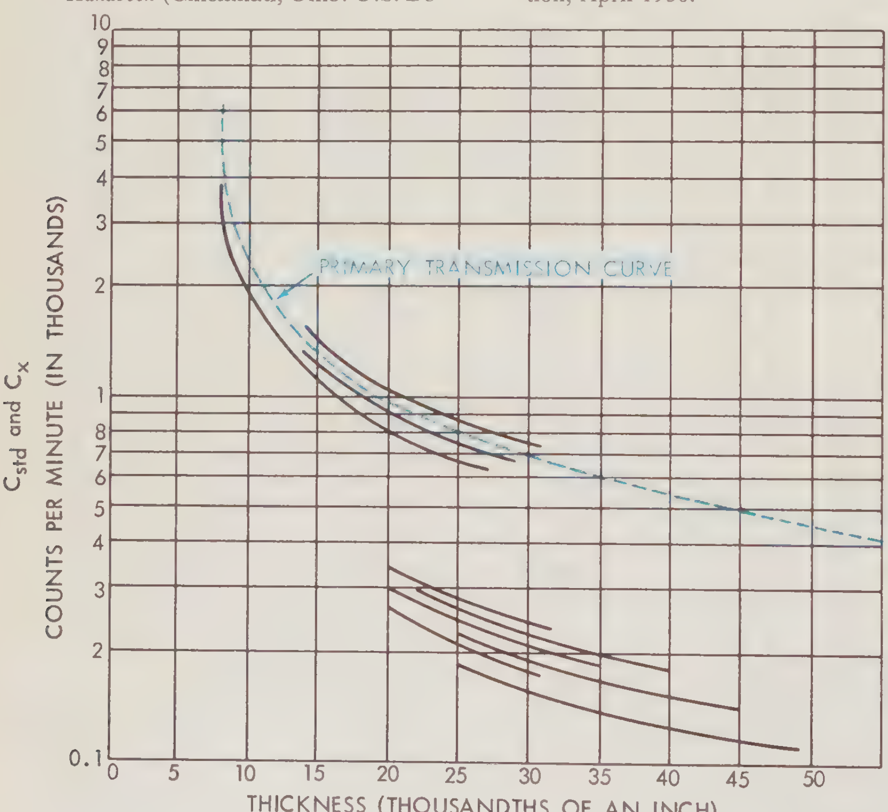


Fig. 7—The primary transmission curve shown here is a plot of the transmission of Sm-153 radiation from a constant source through precisely measured step wedges of GMR-235 alloy covering the complete range of thicknesses to be encountered on the specimens. Also plotted are actual count rate curves at individual positions on standard blades or vanes merely to show the relation of these curves to the primary curve. The difference in levels of these curves is due to the fact that the liquid Sm-153 source size is different at each position because of the geometry of the specimens. These curves are all parallel and each curve is related to the primary transmission curve by a constant factor, thus allowing the use of the single primary curve only in the thickness determinations.

Previously published General Motors Engineering Journal papers which deal with the industrial application of radioisotopes include the following:

"GM 'School' Trains Personnel in the Industrial Application of Radioisotopes," Vol. 4, No. 4 (October-November-December 1957), p. 17.

"Radioisotope Measuring Gage Applied to the Production of Storage Battery Separators," Vol. 5, No. 1 (January-February-March 1958), pp. 34-5.

Green, Farno L., "Studies of Radioisotopes Show Promise for Present and Future Applications in Engineering," Vol. 5, No. 2 (April-May-June 1958), pp. 17-20.

Gambill, Charles C., "An Application of Radioisotope Wear Study Techniques," Vol. 5, No. 2 (April-May-June 1958), pp. 21-5.

Beacom, Seward E., and Riley, Bernard J., "A Radioisotopic Study of Leveling in Bright Nickel Electroplating Baths," Vol. 6, No. 2 (April-May-June 1959), pp. 20-7.

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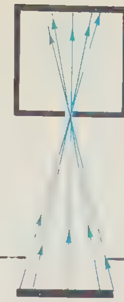
New Camera Takes True Pictures of Conditions Inside Cylinder Liner During Developmental Tests



By HOWARD A. GROOMBRIDGE
Detroit Diesel Engine Division

A new use for the old principle of the pinhole camera

A difficult photograph to obtain is one showing the inside appearance of a cylinder liner of a Diesel engine undergoing developmental tests. Such was the case at Detroit Diesel Engine Division, where various photographic methods were applied in an attempt to obtain pictures which would show the true condition of cylinder liner air-inlet port deposits and cylinder wall conditions at various stages of an engine test program. None of the methods proved entirely successful. Often inaccurate and deceptive, the pictures obtained represented little more than a photographic note that a test had been made. A better photographic method was in order. Such a method resulted with the development of a unique camera, the operation of which is based on the principles of the simple pinhole camera. The new camera, referred to as a *liner camera*, provides distortion-free pictures of a cylinder in its true condition. Simple to operate, the liner camera also provides the desired pictures in less time and at less cost than required by the former methods.

One phase of the engine testing program at Detroit Diesel Engine Division involves recording, by photographic methods, the appearance of cylinder liner air-inlet port deposits and cylinder wall conditions during and after a test. Such records are valuable to design engineers when evaluating various design and material changes.

Various photographic methods (Fig. 1) have been used to record the cylinder liner conditions such as: (a) conventional angular views of the port area, (b) pictures taken of the port area reflected from a conical mirror resting on top of the piston, and (c) the use of positive paper inserted into the liner and held in place against the liner wall by an inflated balloon.

In general, the pictures obtained by these methods have been deceptive and have represented little more than a photographic note that a test was made. The methods left much to be desired. As a result, steps were taken to develop a more useful and reproducible photographic technique.

New Camera Provides Distortion-Free Pictures

One of the simplest and most basic of cameras is the pinhole camera which uses an extremely small diameter hole instead of a lens to admit light rays. The theory of image formation by means of a pinhole was the basis upon which a camera was developed to photograph cylinder liner conditions. This camera, referred to as a *liner camera* (Fig. 2), allows the air-inlet port deposits and cylinder wall conditions to be photographed at any time during the test period. All that is required is removal of the cylinder head to allow the camera to be inserted into the liner bore on top of the piston when the ports are fully exposed.

The liner camera provides a picture showing the complete liner in its true condition with no distortion (Fig. 3). Two pictures are taken inside each liner, one of the blower side and the other opposite the blower. Each picture covers slightly over 180° of the liner and, when spliced together, the resulting picture shows the true condition of the entire liner area.

The liner camera, which has good depth of field (Fig. 4), is extremely simple to operate. After the camera is inserted into the liner, a bulb shutter is opened. (The pinhole, or aperature opening, is so small that available light has no apparent effect on exposure.) A No. 5 flash bulb is then fired above the liner and its duration of approximately 1/50 of a second controls the exposure time. The shutter is then closed, the camera removed, film changed, and the camera is ready for the next exposure.

Sharpness of Pictures Depends on Pinhole Diameter

The principle of the pinhole liner camera is that a very small hole admits only one ray of light from any given point on an object in front of the camera. Light rays from all points on the object enter the pinhole and form an image on the film plane of the camera.

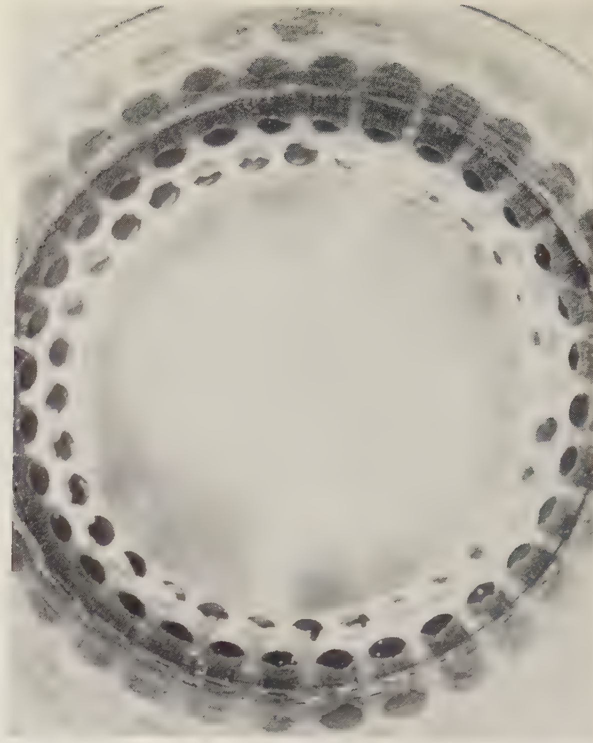
In the design of the liner camera, the first problem to be solved was construction of a film plane in which there would be no apparent distortion. The pinhole principle has the important quality of universal focus—that is, the focal length can vary without causing an out-of-focus condition. It was only necessary, therefore, to hold the ratio of the film plane to the subject plane constant through the pinhole (Fig. 5).

After the body of the camera was constructed, it was necessary to provide a pinhole of the proper diameter that would give the sharpest pictures possible. If too large a pinhole was used, a fuzzy or blurred image would be formed due to the large number of light rays admitted and their overlap on the film plane. Likewise, too small a pinhole would increase the exposure time and decrease the angle of coverage. Thus, an optimum diameter pinhole was necessary to give the best overall sharpness and a reasonable exposure time.

Of equal importance was the condition that the pinhole be perfectly round and have clean edges. The thickness of the material in which the pinhole would be made and the diameter of the pinhole would control the maximum angle of coverage.

Various pinhole diameters ranging from 0.030 in. to 0.009 in. were tried during the development of the liner camera. The larger diameter pinholes allowed shorter exposure times and covered wider angles. The best overall results, however, were obtained with a 0.012-in. diameter pinhole made in 0.0015-in. thick stock. This gave an angle of coverage of 165° and covered 192° of

a

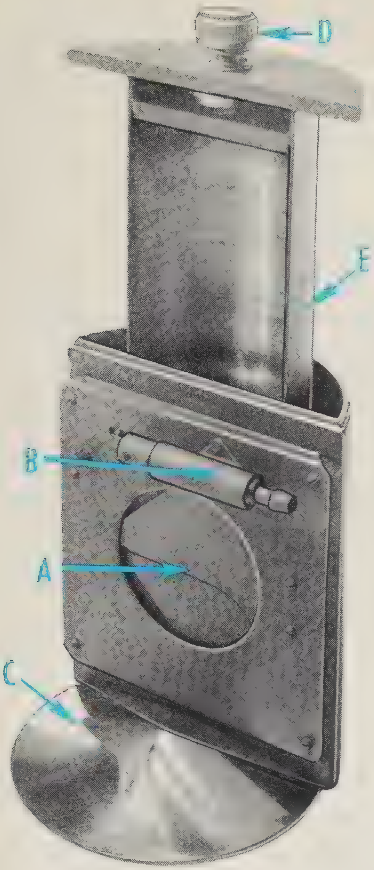


c

b


NEW LINER
"0" HOURS
LINER NO. 1
1067 HOURS
LINER NO. 2
852 HOURS
LINER NO 3
1067 HOURS
LINER NO. 4
852 HOURS
LINER NO. 5
HOURS
LINER NO. 6
93 HOURS

d



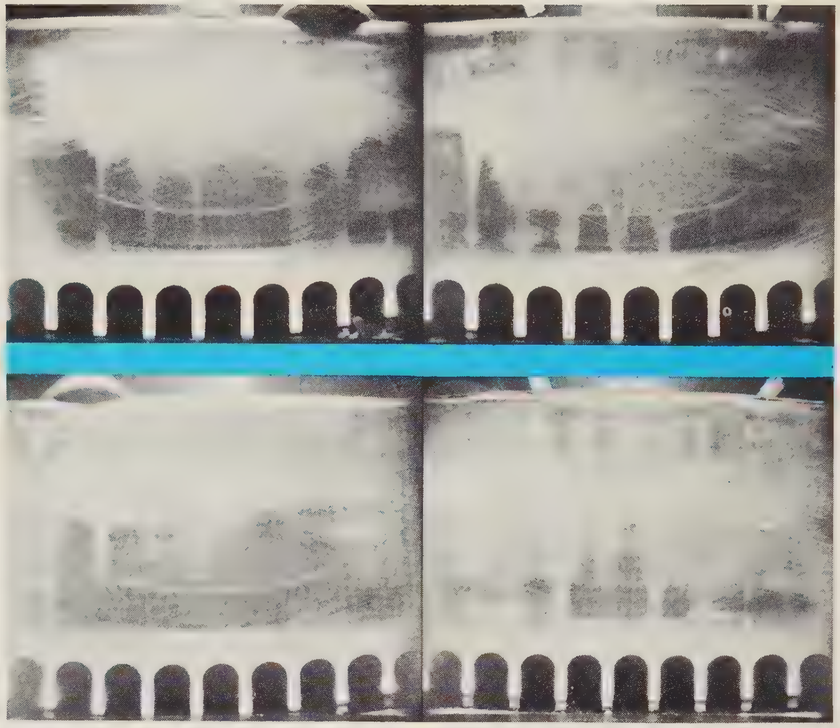


Fig. 3—The pictures provided by the liner camera show the liner ports in a true condition with no distortion. Two pictures, as shown here, are taken inside each cylinder liner, one picture of the blower side of the cylinder and the second picture opposite the blower. Each picture covers slightly more than 180° of the liner. When spliced together, the condition of the entire liner area is shown.

Fig. 2—Shown here is the liner camera developed at Detroit Diesel to photograph conditions inside a cylinder liner at any time during an engine test period. The liner camera, based on a simple pinhole camera, has a 0.012-in. diameter pinhole in place of a lens. The pinhole admits only one ray of light from any given point on an object in front of the camera. These light rays enter the pinhole from all points and form an image on the film plane of the camera. To use the camera, the cylinder head is removed when the ports are fully exposed. A bulb shutter *A* is then opened. (The shutter has an operating piston *B*). The pinhole is small enough so that available light has no apparent effect on exposure. A No. 5 flash bulb is then fired above the liner and its 1/50-sec duration controls the exposure time. The shutter is then closed, the camera removed, and film changed in preparation for the next exposure. Sufficient lighting of the port area is provided with the aid of a cone reflector *C* installed at the base of the camera. Other components of the camera include a spring loaded light-tight lock *D* and film holder *E*.

the subject plane (Fig. 6). The various diameter pinholes were made by carefully hand drilling through 0.0015-in. thick steel feeler stock.

Some difficulty was encountered in lighting the subject plane. Various tests were made to find a reflector to put light on the port and liner wall areas. The final result was a cone reflector installed at the base of the camera (Fig. 2).

Why a Pinhole Was Used Instead of a Lens

A pinhole was used instead of a lens because restrictions inside a cylinder liner are such that no lens could be designed to meet all the necessary specifications. This can be illustrated as follows. With a focal length of 2.125 in. (based on a liner bore diameter of 4.25 in.) and a hyperfocal distance of 2.125 in., the f stop would be equal to

$$f = \frac{\text{focal length (1,000)}}{\text{hyperfocal distance}}$$

$$f = \frac{2.125\ (1{,}000)}{2.125} = 1{,}000.$$

With a focal length of 2.125 in. and an f stop of 1,000 the diaphragm diameter D would be equal to

$$D = \frac{\text{focal length}}{f \text{ stop}} = \frac{2.125}{1{,}000} = 0.002125 \text{ in.}$$

Fig. 1—Various photographic methods were used by Detroit Diesel Engine Division to record the appearance of cylinder liner port deposits and cylinder wall conditions before the pinhole liner camera was developed. None of the methods gave entirely satisfactory results. Conventional angular photos of the port area taken from above the cylinder liner (a) were inadequate and inaccurate because of the receding and unrevealing perspective. Pictures of the port area reflected from a conical mirror resting on top of the piston (b) were most difficult to interpret because of distortion. The method used most frequently was based on the use of positive paper mounted strips (c). With this method, positive paper was inserted into the liner and held in place against the liner wall by an inflated balloon. A neon tube light was then inserted in and around the airbox surrounding the cylinder to expose the paper and thereby reveal the unplugged areas of the ports. This photographic method was very time consuming (the engine had to be stripped down to the bare block) and did not always show the true condition of the ports. After recording the liner port condition at the end of a test period, the liners were removed and split (d) to permit an evaluation of the liner condition. Splitting the liner, needless to say, terminated any further testing.

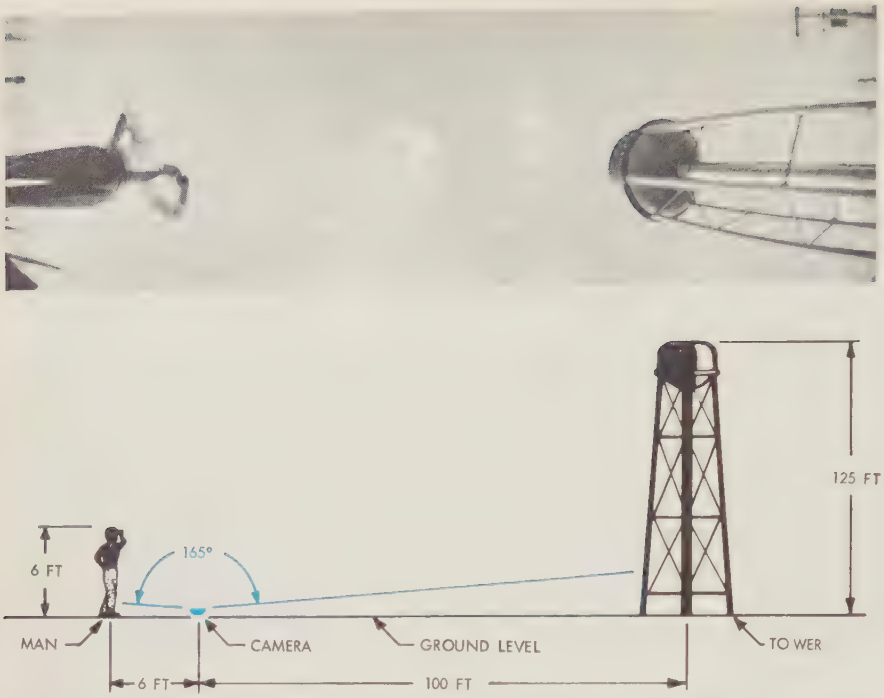


Fig. 4—To illustrate the depth of field of the liner camera, this picture was taken near the Experimental Laboratory at Detroit Diesel Engine Division. In the photograph at the top, blades of grass approximately 2 in. from the lens can be seen near the legs of the man. The water tower is approximately 100 ft away and is 125 ft high. The schematic diagram at the bottom indicates the position of the camera with respect to the man and the tower. The diagram is not drawn to scale. Had the man been drawn to the same scale as the tower, he would have been difficult to see.

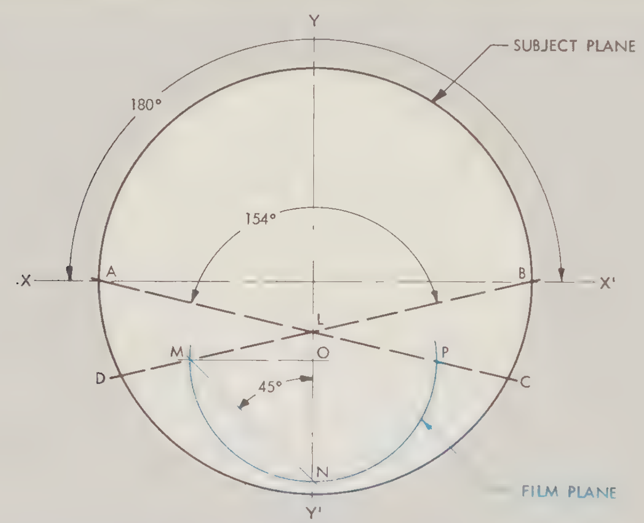


Fig. 5—One important quality of the pinhole principle used in the liner camera is that it has universal focus. In the construction of the film plane, therefore, the focal length could vary without causing an out-of-focus condition and it was only necessary to hold the ratio of the film plane to the subject plane constant through the pinhole. This was accomplished as shown in the diagram. A circle to represent the liner bore (4.25 in. for a Detroit Diesel Series 71 engine) was first drawn. A diameter on the X-X' axis was then marked A-B to indicate the minimum amount of the subject plane (liner wall) to be photographed. A point L, positioned ½ in. from the center and along the Y-Y' axis, was arbitrarily chosen as the position for the pinhole. Lines from points A and B were drawn through point L and extended to points C and D on the circumference of the circle. A point N was then arbitrarily chosen ⅛ in. from the liner wall on the Y-Y' axis. Next, a line was drawn at 45° through point N and extended through line B-D. The intersection of these lines was point M. From point M a line was drawn parallel to the X-X' axis through the Y-Y' axis to establish point O. An arc was then drawn with point O as the center and O-M as the radius. The arc M-N-P formed the film plane. This geometric construction holds the ratio of the film plane to the subject through point L, representing the position of the pinhole. Construction of this diagram showed that any pinhole which provided an angle of coverage of 154° or more would cover 180° of the liner bore.

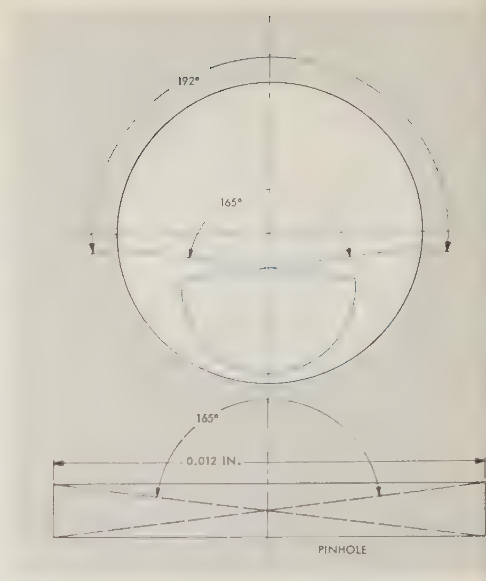


Fig. 6—The liner camera uses a 0.012-in. diameter pinhole made in 0.0015-in. thick stock. The diameter of the pinhole provides an angle of coverage of 165° and covers 192° of the subject plane (liner bore).

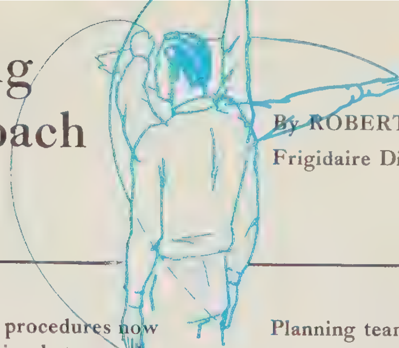
If the lens were to have a coverage of 165°, the thickness of the diaphragm could be only 0.00014 in.

To increase the diameter of the diaphragm, the *f* stop number would have to be decreased or the focal length increased. The focal length, however, could not be increased because of the cylinder bore diameter. If the *f* stop number were decreased and the focal length kept the same, the hyperfocal distance would become greater. Due to the increased hyperfocal distance, the subject plane would be out of focus. If the focal length were decreased and the hyperfocal distance kept constant, the *f* stop would be reduced. But, decreasing the *f* stop to 50 or less would reduce the focal length, placing the film plane so close to the lens that the film size would be almost unuseable.

Summary

In addition to providing a distortion-free picture of the complete liner in its true condition, the liner camera also provides operational economies in the Photographic Department at Detroit Diesel. Pictures can now be taken in less time than it took when using the positive paper method. Also, the liner camera provides a saving in processing time because the negatives can be spliced directly with no retouching or copy negatives required.

Applying Methods Engineering and the Planning Team Approach at Frigidaire Division



By ROBERT J. SCHMIDT
Frigidaire Division

A careful analysis and planning of each production operation is one of the procedures now used in industry to reduce manufacturing costs. To provide the cooperation between the various manufacturing departments that is necessary for a methods engineering program, a *planning team* approach has been devised. An example of the application of this system is found at Frigidaire Division, which uses a planning team to solve new model assembly problems. The planning team, working with other departments, guides the product from the design stage to the final assembly line. By using a methods laboratory to plan each production operation and to train the machine operators, assemblers, and supervisors, the team prevents many production problems. A 4 ft by 8 ft planning board, containing photographs and charts illustrating the manufacturing operations, provides the communications necessary for the success of the Frigidaire methods engineering program.

Planning team provides a coordinated approach to production problems

UNTIL recently in America's industrial history, planning a manufacturing operation in a plant usually meant merely answering the basic questions of "*What* is to be done?" and "*Where* is it to be done?". Decisions on the manual methods to be used in performing each operation often were the responsibility of the production foreman or the person operating a machine. However, as technology advanced and the demand for more and better products grew, the demand for more efficient manufacturing also grew.

To improve this efficiency, attention was concentrated in the planning stages of manufacturing operations on a third basic question: "*How* is it to be done?". The task of finding the *best method* of performing a particular manufacturing or assembly operation no longer could be overlooked. This led to the development and application of what is now called *methods engineering* programs. Probably there are as many definitions for methods engineering as there are companies using it. In General Motors, it is defined as:

> "The analysis and planning of man-job relationships for the purpose of establishing the most economical use of manpower, materials, and facilities."

General Motors methods engineers further describe it as a program that assists in planning the most economical tooling, equipment, material handling facilities, and work place layout, and guides the training of the machine operators. It may even suggest simplification of the product.

Methods engineering can be used either to plan new manufacturing operations or to improve existing operations. However, a methods engineering program cannot be successful unless it is coordinated with every department concerned with the designing or the manufacturing of the product. To help provide this cooperation, a *planning team* approach has been developed.

How the Planning Team Functions

Two principal responsibilities are assigned to the planning team: (a) to develop the most effective plan for manufacturing the product, and (b) to assist in putting the plan into operation.

The nucleus of a planning team usually consists of a process engineer or tool engineer, a plant layout engineer, and a methods engineer, although other individuals may be brought into the planning as it progresses. One of these engineers is named the team leader, or coordinator. While each engineer represents his department during the planning process, he also must consider the job functions of the other team members when compiling his section of the manufacturing plan.

Various divisions of General Motors may handle their methods engineering programs in different ways. The following example explains how Frigidaire Division uses the planning team approach in its methods engineering program to solve a manufacturing problem.

Problem: Plan the assembly of an electric range control panel

Objective: Plan, design, and build the panel for the most effective use of manpower and facilities

Approach:

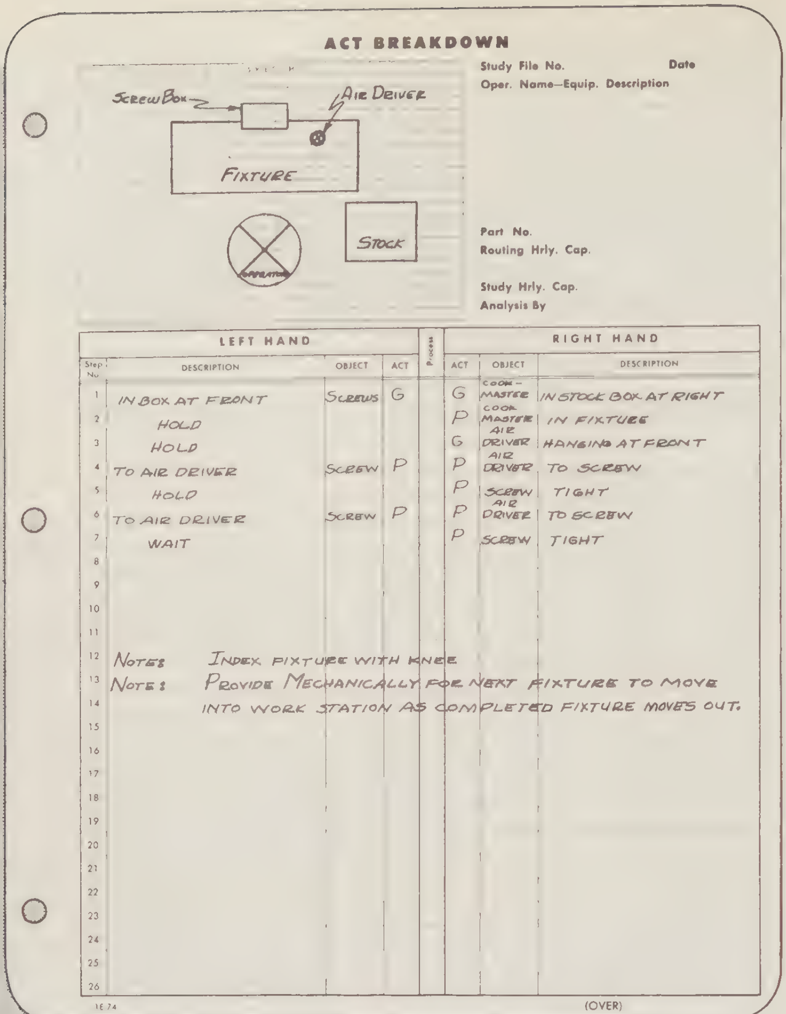
(a) Plan each employe's manual method
(b) Recommend the necessary tools and equipment
(c) Provide work place layouts.

The team starts its planning while the control panel is in the design stage so that any manufacturing problems created by the design can be discussed and corrected. During this period each member of the team begins to familiarize himself with the product and to develop ideas for the best way to manufacture it. At this time, changes in design may be recommended to correct any difficulties existing in the production of the current model control panel.

Methods Laboratory Permits Study of Production Problems

When the preliminary design of the control panel is completed, a handmade working model is built in a model shop. The planning team uses this model in the methods laboratory to plan the steps necessary to produce the control panel. Actual production operations are simulated in the laboratory so that the planning team can study and evaluate new ideas, develop new fixtures, and try out the manufacturing equipment. The model is repeatedly disassembled and reassembled to permit each member of the team to evaluate the product according to his area of responsibility. After a tentative sequence and method of assembly has been proposed, the control panel is reassembled while the methods engineer records the procedure by means of motion pictures or photographs. This information is used later to help determine the final assembly sequence.

Since the model usually is available to the planning team for only a few days,



ACT BREAKDOWN

Study File No. Date
Oper. Name—Equip. Description

SCREW BOX
AIR DRIVER
FIXTURE
STOCK
OPERATOR

Part No.
Routing Hrly. Cap.

Study Hrly. Cap.
Analysis By

	LEFT HAND				RIGHT HAND		
Step No.	DESCRIPTION	OBJECT	ACT	Process	ACT	OBJECT	DESCRIPTION
1	IN BOX AT FRONT	SCREWS	G		G	COOK-MASTER	IN STOCK BOX AT RIGHT
2	HOLD				P	COOK MASTER	IN FIXTURE
3	HOLD				G	AIR DRIVER	HANGING AT FRONT
4	TO AIR DRIVER	SCREW	P		P	AIR DRIVER	TO SCREW
5	HOLD				P	SCREW	TIGHT
6	TO AIR DRIVER	SCREW	P		P	AIR DRIVER	TO SCREW
7	WAIT				P	SCREW	TIGHT
8							
9							
10							
11							
12	NOTES: INDEX FIXTURE WITH KNEE						
13	NOTE: PROVIDE MECHANICALLY FOR NEXT FIXTURE TO MOVE						
14	INTO WORK STATION AS COMPLETED FIXTURE MOVES OUT.						
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							

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Fig. 1—Shown above is a work breakdown made by a Frigidaire Division methods engineer for one of the operations in the assembly of the electric range control panel. The form lists the operations to be performed by each hand plus a sketch of the work location. The *G* in the Act column stands for *Grasp* and the *P* for *Place*. The production foreman receives a methods breakdown, or operator instruction sheet, for each operation before production begins.

the films also can be used as a reference in future meetings with other persons involved in the planning of the new product.

During this analysis and reassembly stage, the team recommends additional design changes. Close liaison between the product design engineers and the planning team is maintained since this is probably the critical period in the planning activity. Decisions that affect tools, die design, assembly sequence, process and operator methods are made promptly. Although the discussions are informal and any commitments are made verbally, the planning team proceeds with the assurance that design changes will be adopted by the engineering department. At this stage of the planning, the production foreman attends the discussion periods in the methods laboratory to become familiar with the new model and the production problems involved, and to make suggestions regarding the production methods.

After the analysis is completed in the methods laboratory, the planning team adopts a tentative plan for manufacturing the control panel. This plan—to be carried out properly—usually requires certain changes in product design. Therefore, the planning team submits to the engineering department a letter containing the recommended product design changes, supported by the necessary data and economic justification. A follow up meeting is held with representatives of the engineering department to review these changes and to settle upon the final design.

The methods engineer, by analyzing the films that were taken during the reassembly of the panel in the methods laboratory and using the GM Predetermined Motion Time System*, then develops a prescribed operator method (Fig. 1) and the estimated cycle time for each operation. The process engineer determines what mechanical equipment is required. The fixture designers, who work closely with the methods engineer and process engineer, complete the design of fixtures that will enable the prescribed operator methods to be followed in using the necessary tools and equipment. From this information, the layout engineer completes his work place layouts (Fig. 2).

The planning team then condenses this information into a final manufacturing plan which is presented at a meeting of the department heads of those staff functions concerned with planning or producing the product, such as the plant manager, the production superintendents, and the superintendents of the Inspection, Material Control, and Mechanical Departments. This meeting provides the plant management with the opportunity to review and approve the manufacturing plan before it is placed in operation.

When the manufacturing plan is approved, the methods engineer organizes the *planning board*, a 4 ft by 8 ft portable bulletin board mounted on a stand, which contains a schematic outline of the overall plan (Fig. 3). The board is a convenient method of illustrating the plan or the details of a specific operation to management, supervisory personnel, or assembly employes.

When the various fixtures arrive at the plant from outside suppliers, the process engineer and methods engineer check each one for any corrections or modifications which are sometimes necessary due to last minute changes in dimensions or tolerances. The production foreman then examines the approved fixtures and learns their proper uses.

Another step at this stage of the planning is to provide an opportunity for the work standards engineer to become familiar with the work place layouts and the new operator methods. Although he is not a member of the planning team, he is consulted frequently throughout the planning process since his department

*A Predetermined Motion Time System is any plan for relating predetermined times for muscular movements to manual method. It is a set of refined and detailed standard time data. It can be used, for example, to evaluate one method against another or to establish the time for a proposed method.

will make a time study of the manufacturing plan when production begins.

The manufacturing plan then is reviewed on the planning board with the production foreman so that he will know how many employes he will need, what their duties will be, and how each operation is to be performed. This review helps him visualize his part in reaching the manufacturing objectives and places him in a better position to train the employes.

The plan is now ready for its first test. A pilot assembly line is set up in the methods laboratory and equipped with the required power tools and fixtures. A preproduction run of several units of each model control panel to be produced (for different electric range models) is scheduled. Production employes are brought into the methods laboratory to build the pilot models under the supervision of the production foreman or the methods engineer (Fig. 4). While certain individuals are retained in the laboratory throughout the pilot run (because of the nature of a particular assignment), the planning team attempts to train as many different employes as possible. Experience has shown that:

(a) The amount of instruction needed at each work station when the model begins production in the plant is reduced when the employe is acquainted with the job procedures

(b) The more training an employe receives, the more enthusiastic and cooperative he is when production begins.

During the pilot run other departments also begin to become more acquainted with the product. For example, Material Control Department personnel become familiar with new parts and their usage while Quality Control Department supervisors are able to forecast quality standards and the type of control necessary for production operations.

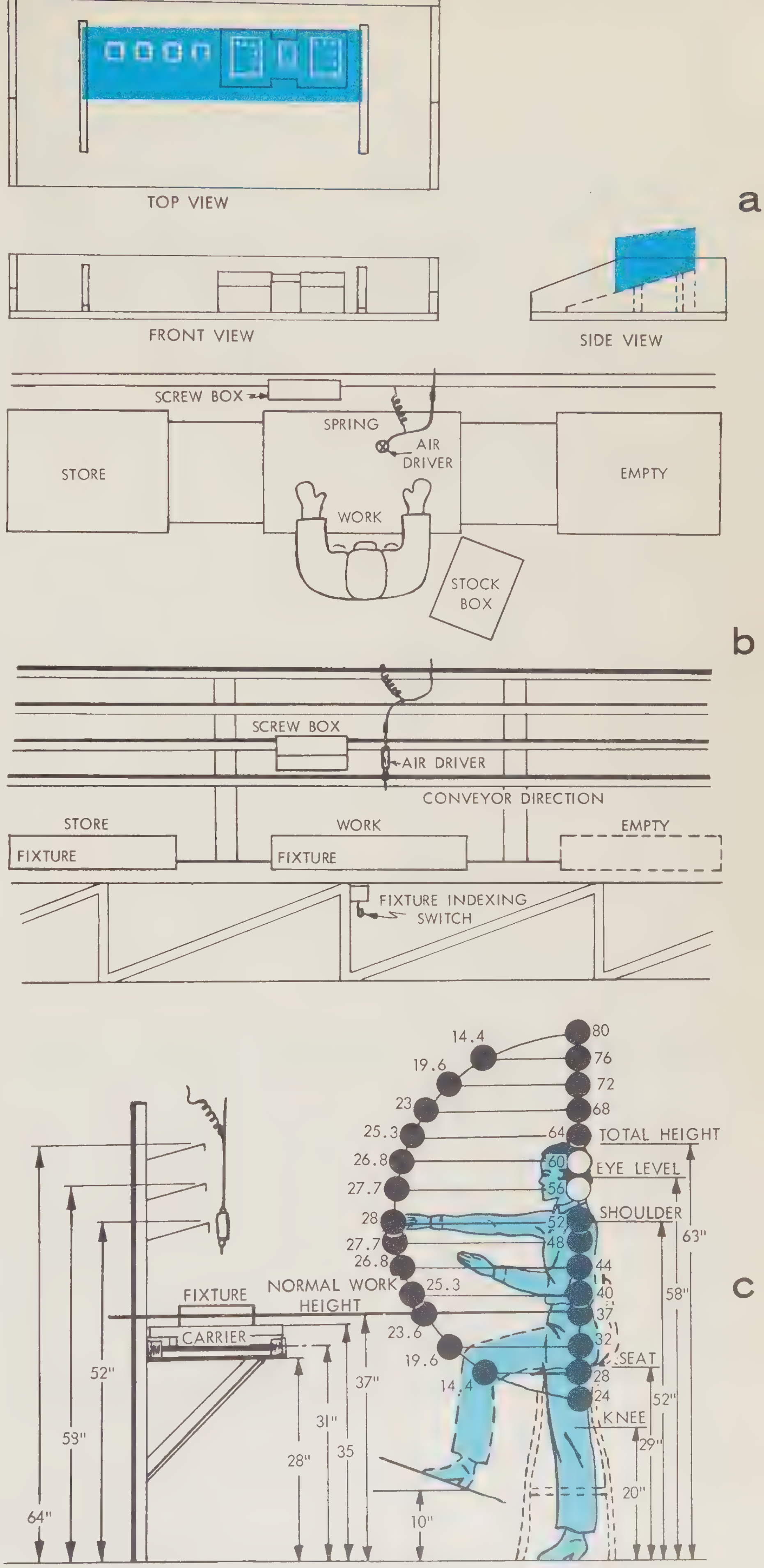

Fig. 2—A simple fixture design of the type shown in (a) is proposed for the new assembly operation. The control panel is positioned and held on the supports during the work cycle. A typical work place layout of one station on the conveyor line is shown in (b). In preparing the physical layout of the work place (c), the layout engineer is guided by recommended dimensions for proper work height, minimum length of reach, convenient stock location, and the size and type of stock containers.

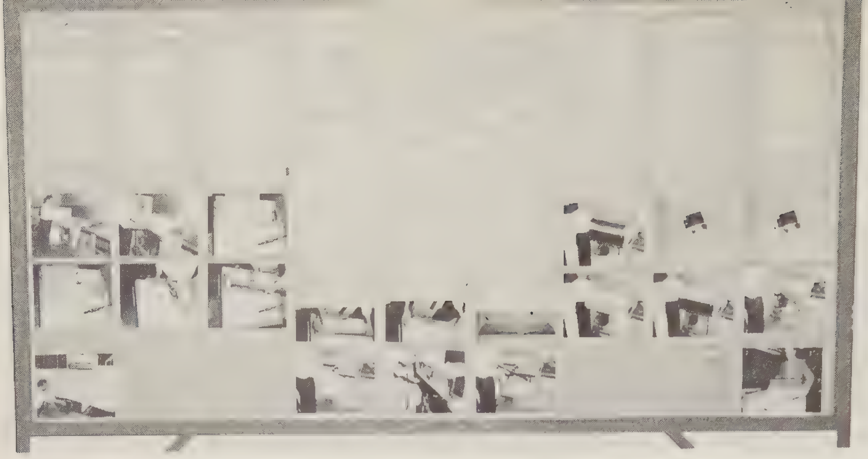

Fig. 3—This is the type of planning board used by Frigidaire Division. The departmental layout is centered on the board and each work station is identified. Assignments are listed for each operation station. Photographs, taken during the product analysis in the methods laboratory, are used to show the assembly sequence. Other information included is the operator cycle time and work load, parts required, and photographs of new parts with their identification numbers and usage. The preparation of a predetermined work assignment for each work station insures that the work will be distributed evenly among the employes.

The Planning Moves from Laboratory to Production Area

The work of the planning team is done principally in two locations: the methods laboratory and the production area. This is an indication of the dual responsibility of methods engineering, which is: (a) to develop a plan, and (b) to assist in implementing it.

As the pilot run is being completed in the methods laboratory, the planning activity concentrates on the job of putting the approved manufacturing plan into operation. One of the early steps is to move the planning board into the production department for reference by the production foreman, who is in charge of installing the plan. Planning team members assist the foreman when necessary. Maintenance Department employes rearrange the production area according to the layout provided by the layout engineer on the planning team. New equipment, benches, and assembly fixtures are installed at this time. After this work is completed, the new parts and materials, which make up the product, are delivered from the Material Control Department. The final arrangement of the assembly line equipment, parts, and materials is then made in accordance with the information on the planning board. The use of the planning board here helps eliminate confusion and keeps to a minimum the time required to set up the new assembly line. Regular production of the new model control panel then proceeds. The planning team remains in touch with the foreman during the first few weeks of production to assist further as needed.

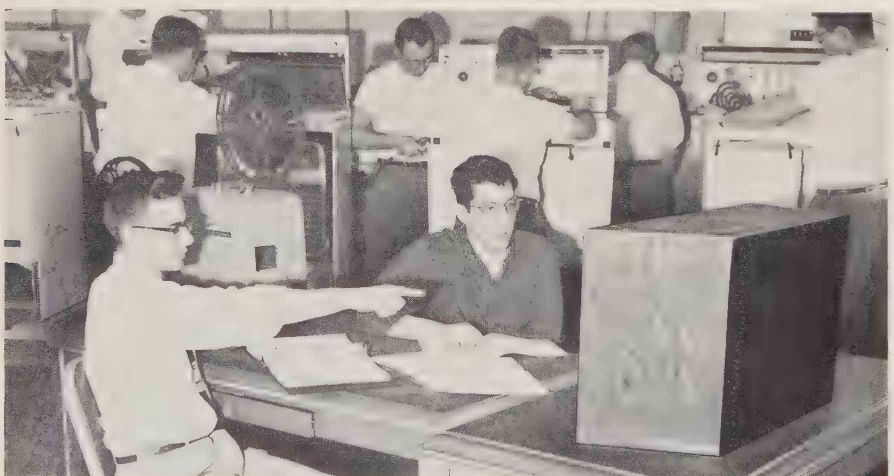

Fig. 4—During the pilot run in the methods laboratory, a methods engineer uses motion pictures to demonstrate the correct assembly procedure to a production department employe. The films were taken several weeks before the pilot run while the product was being studied by the planning team. Use of motion pictures provides both a visual demonstration and an audible explanation of the prescribed assembly methods. Employes in the background are building pilot models under simulated production conditions.

Conclusion

Experience has shown that there are several advantages when using the planning team approach in a methods engineering program:

(a) The cooperation between the planning team and the design engineers enables the product to be designed with a minimum of production problems

(b) The cooperation between the members of the planning team helps to reduce last minute changes in operator methods, type of equipment, and work place layouts

(c) The production foreman has confidence in the manufacturing plan because he has contributed his recommendations to the planning, he is familiar with the operations and objectives of the plan, he has obtained experience with the prescribed methods for each operation, and he has received the answers to any of his questions about the plan.

Many General Motors plants experience major new model changes every year. It is necessary that the planning for these products be thorough and accurate so that method, process, layout, and tooling changes after production will be held to a minimum. Proper use of a methods engineering program and the planning team approach permits lower manufacturing costs through the careful and effective coordination of all personnel connected with manufacturing planning.

Bibliography

Related literature in this field includes the following:

Farley, R. R., "Some Principles of Methods and Motion Study as Used in Development Work," *General Motors Engineering Journal*, Vol. 2, No. 6 (November-December 1955), pp. 20-25.

Maynard, H. B., Stegemerten, G. J., and Schwab, J. L., *Methods-Time Measurement* (New York: McGraw-Hill Book Company, Inc., 1948).

McLandress, R. D., "Methods Engineering for More Effective and Economical Use of Manpower," *General Motors Engineering Journal*, Vol. 1, No. 3 (November-December 1953), pp. 28-30.

Nadler, Gerald, *Motion and Time Study* (New York: McGraw-Hill Book Company, Inc., 1955).

Some Advantages Provided by Transistors When Used in Industrial Inspection and Control Instruments

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The small transistor
provides big
benefits

Much has been written concerning the differences between vacuum tube and transistor circuitry from a design standpoint. The various advantages and limitations of each, such as voltage, current, and impedance levels, temperature effects, and expected life have been covered extensively in the literature. Transistors and related semi-conductors, however, have a number of less publicized advantages, especially in their application to industrial inspection and control instruments. Some of these advantages have become apparent in the design, development, and fabrication of such instruments in the Electronics Department of the GM Manufacturing Development Staff.

ONE of the functions of the Electronics Department of the GM Manufacturing Development Staff is to design, develop, and build inspection and control instruments to meet specialized requirements of some GM Divisions (Fig. 1). Such instruments are used to improve manufacturing equipment and processes. During the past few years increased use has been made of transistors and related semi-conductors in the design of such instruments. The experience gained has shown that transistors have certain advantages, as well as disadvantages, when applied to circuit design, development and mockup, circuit packaging, and instrument fabrication.

Transistors Provide Flexible Circuits

In general, transistor circuits require more thorough design than their vacuum tube counterparts. Although transistors are continually improving, not all of their characteristics are consistent from unit to unit, and they vary greatly with temperature. In many cases, these variations will result in unstable circuit performance unless suitable compensating elements and safety factors are included.

Because of the non-isolation of input and output circuits, impedance matching is sometimes more difficult with transistors than with vacuum tubes. This makes it more difficult to design a system stage-by-stage and to use previously designed stages without considering the overall circuit. These apparent disadvantages, however, are offset by the fact that the additional engineering time spent results in circuits which, when produced, are electrically consistent and relatively independent of component parameters over a known temperature and supply voltage range.

Greater flexibility is one of the advantages of transistors in industrial instrument applications. The choice of polarities provided by the availability of NPN and PNP types of transistors simplifies the design of direct coupled amplifiers or other circuits where the input or output must be at a particular d-c level.

A unique scheme possible with transistors is complementary symmetry, which makes use of a matched pair of NPN and PNP transistors to produce a simple, stabilized, symmetrical amplifier stage (Fig. 2). In an audio amplifier the use of complementary symmetry often eliminates the need for output or interstage transformers, since no quiescent current flows in the load. Where a transformer is required for impedance matching purposes, the absence of a d-c component reduces distortion problems.

One factor which has restricted the use of complementary symmetry to date is the limited availability of closely matched NPN-PNP pairs. With the exception of silicon switching transistors and a few relatively expensive high-power amplifier types, there are few exactly matched pairs available. In some cases, exact matching is not necessary, but in other cases the lack of matched pairs prevents the use of an otherwise versatile circuit.

Another way transistors increase circuit flexibility is through their adaptability to *floating circuits*. (A circuit is said to be floating if no point in the circuit is held at a fixed potential with respect to the supply voltage.) With vacuum tubes it usually is necessary to maintain the cathode at a potential near ground or else use special filament biasing arrangements to prevent excessive heater-cathode leakage with resultant hum and breakdown problems. This problem does not exist in transistor floating circuits, and any one of the three terminals may be biased at any convenient level as long as the terminal-to-terminal voltage ratings are observed. The lower impedance levels usually associated with transistor circuits also make capacitance-to-ground a less severe problem.

Perhaps the most important advantage of transistors from the circuit design standpoint is their compatibility with other semi-conductor devices which are in existence or being developed. These include voltage reference diodes, controlled rectifiers and trigger devices, Hall-effect devices, photo-electric and infra-red transducers, voltage-variable silicon capacitors, and temperature sensitive resistors. Many of these devices have no vacuum tube counterpart. Transistors also are well suited for driving magnetic circuits where a low voltage, high current source often is desirable.

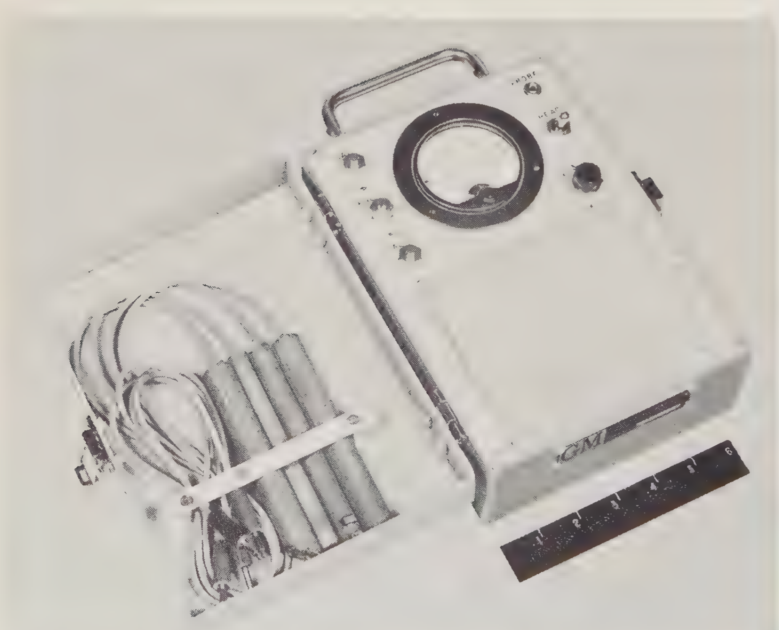
In switching applications, transistors are advantageous because of their low power dissipation and resulting high efficiency. Silicon controlled rectifiers presently available are capable of switching power levels on the order of five kilowatts at over 99 per cent efficiency. The absence of a filament and the low saturation voltage contribute to this high efficiency.

Transistors Simplify Development and Mockup

Experience has shown that it usually is advisable to construct a breadboard mockup of a major portion of any transistor circuit prior to final buildup. Transistors permit quick and convenient building of mockups. The reduction in size and weight of components used in

a

b



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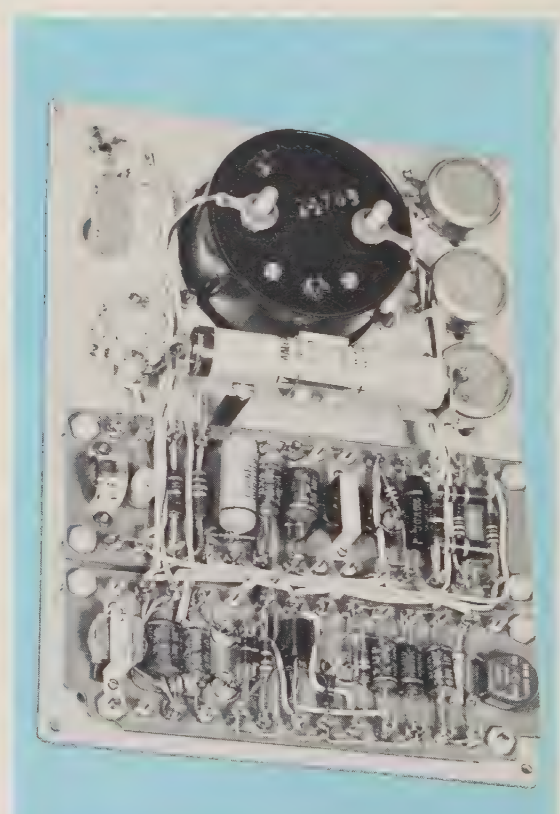

Fig. 1—Shown here are two typical transistorized industrial inspection and control instruments designed and built by the Electronics Department of the GM Manufacturing Development Staff. A transistorized ground locator (a) is used to pinpoint ground faults in plant electrical power and lighting systems without interrupting service. The use of transistors made it possible to reduce considerably the size and weight of this instrument compared to the previous one. An example of a transistorized instrument developed for a specialized application is a thickness gage (b). The underside of the thickness gage with its circuit layout also is shown (c).

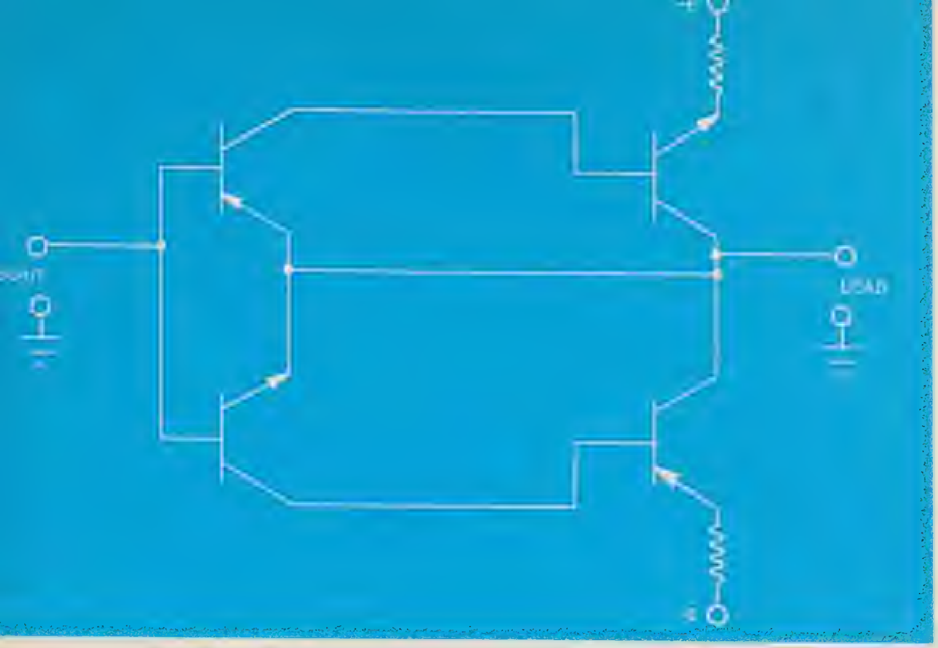

Fig. 2—One advantage provided by transistors in circuit design is complementary symmetry, which makes use of a matched pair of NPN and PNP transistors to produce a simple, stabilized, symmetrical amplifier stage. The circuit shown here is for a low power d-c amplifier. The simplicity of the circuit provided by complementary symmetry is apparent. The complete power amplifier contains only four transistors and two resistors.

transistor circuits permit most of them to be "haywired" directly to terminal boards without any other means of support (Fig. 3). This includes transformers, except perhaps in power supplies and high power output stages.

The fact that all components are soldered in makes for easy circuit changing. Another improvement to circuit changing is the elimination of the warm-up period after the power has been turned on again. In addition, the low operating voltages of transistors provide a safety feature not possible with a vacuum tube mockup. Also, the elimination of filament wiring saves time and reduces hum pickup problems.

Due to the generally low impedance levels involved with transistors, shielding is seldom required and lead placement is not especially critical, except in high frequency circuits. The low impedance also makes it possible to use a wide variety of test and measuring instruments without loading the circuit.

Finally, and most significantly, the layout of a transistor mockup usually bears a close resemblance to the schematic diagram and to the layout of the finished equipment (Fig. 4).

Transistors Simplify Circuit Construction and Enclosure

The most striking characteristic of transistors, of course, is their small size. This, combined with their low heat output, resistance to shock, disregard for mounting position, and light weight make for easy circuit packaging (Fig. 5). Not only are the methods of circuit layout and construction virtually limitless but often one basic layout will fit many different physical configurations and types of containers.

The light weight and resistance to shock features of transistors make it possible to mount transistorized control circuitry directly on moving members of a controlled machine. In addition to saving cabinet space, this reduces the number of interconnecting cables needed and lessens the chance for hum or transient interference pickup.

The use of transistorized circuitry has made it possible to reduce the size of electronic equipment by five times with no crowding of circuits. Miniaturization has not been a major objective in industrial electronic equipment in the past, but it has some advantages not generally recognized. It is possible to put more circuits on one chassis, saving troublesome interconnections, or to build them on small, lightweight plug-in cards. The reduction in size and especially the reduction in weight simplifies and reduces the cost of the enclosure or console required. By installing the electronic circuits on an existing panel or directly on the machine, it often is possible to eliminate a separate cabinet entirely.

In general, the inspection and control systems designed by the Electronics Department are built in quantities of one or two. The techniques described and the results obtained, therefore, are based on situations where a substantial amount of time could not be spent optimizing the circuits and layout. Changes after construction, however, brought about by changing requirements frequently necessary when equipment is built in this fashion, have brought to light another advantage of transistorized equipment. Since most components are mounted only by their leads or in simple clips or brackets, it is not necessary to re-work the chassis to make major changes. There

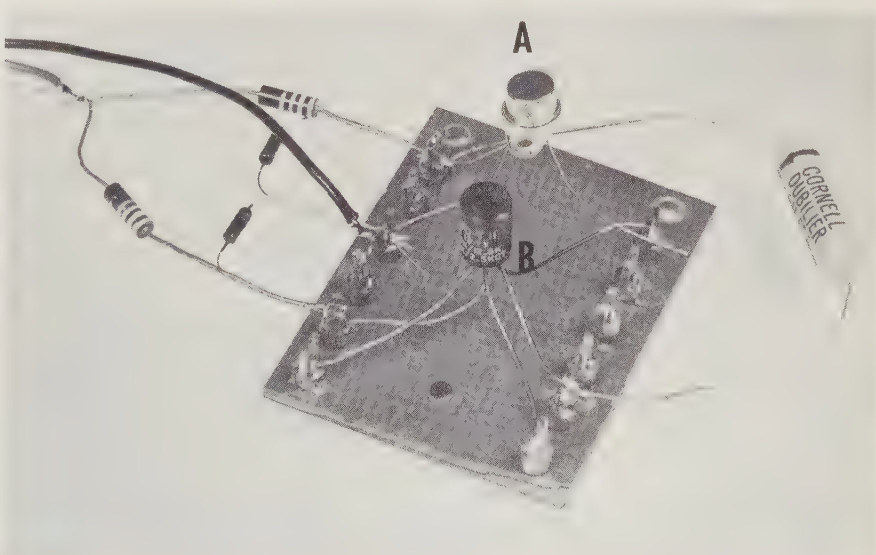

Fig. 3—Breadboard mockup of transistorized circuits is a quick and convenient operation. Illustrated here is a "haywire" mockup showing a transistor *A* and transformer *B* wired directly to a terminal board without any other means of support.

are no empty tube sockets or transformer mounting holes to detract from the appearance, as is often the case with vacuum tube equipment.

Construction of transistorized circuits is usually faster than corresponding tube circuits for several reasons. There is less chassis punching, drilling, and other sheet metal work required. The wiring layout, in most cases, is flat, one-sided, and accessible. There is no filament wiring, little shielding, less interconnection wiring, and fewer connectors. The associated cabinets and hardware are simplified. Blowers and fans are seldom required, although it may be necessary to construct or install heat sinks on some of the transistors. Where production quantities warrant them and the circuit has been finalized, the use of printed circuits can save wiring time and reduce errors.

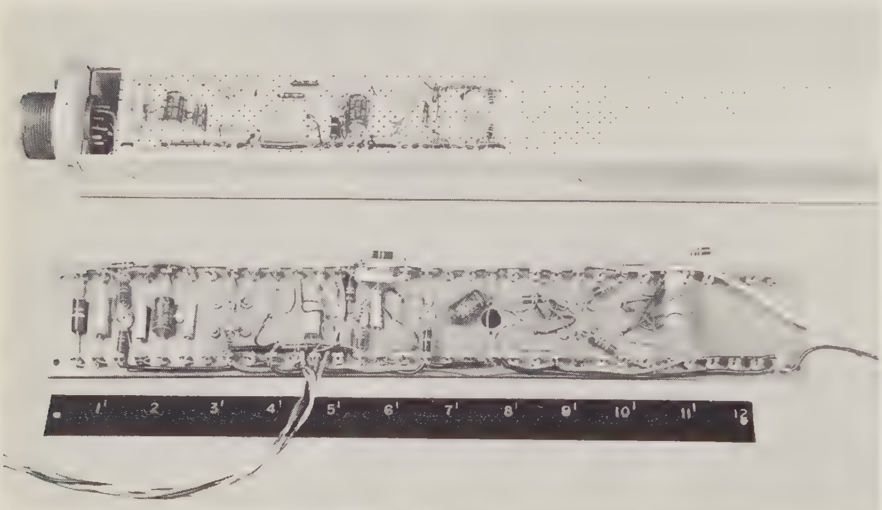

Fig. 4—The layout of a transistor mockup bears a close resemblance to the final unit. Shown here is a comparison between a transistor mockup (bottom) and a production model (top) of a transistorized carrier amplifier and modulator for use with a displacement transducer. The mockup served as a model when the final unit was built. This eliminated problems of unintentional interstage coupling and interference which often develop when the layout is changed. Also, the close similarity between the mockup and final unit reduces "debug" time because the engineer familiar with the mockup can quickly find a fault in the final circuit.

Transistors Provide Specific Operational Advantages

The nature of machine environments is such as to subject electronic circuits to localized airborne oil, dust, grit, and fumes. In spite of filters in the cooling system of vacuum tube circuits, these contaminants eventually cover the entire circuit with a coating of low-resistance slime. Transistorized equipment, on the other hand, can be completely sealed to prevent the entrance of these contaminants. Any heat that may be generated in the circuit can be conducted to external radiating fins, making it unnecessary to circulate air through the chassis.

If it is desired to operate the transistorized circuit while immersed in a liquid it can be encapsulated in potting compound for complete protection. The small amount of heat generated by the transistors helps to extend the life of adjacent components.

A summary of operational advantages provided by transistorized instruments includes:

- Instant operation (no warm up)
- Low or zero standby current
- Fewer problems of hum and transient interference
- Light weight (important in portable instruments)
- Ease of servicing, because of the simplified layout
- Ability to use low impedance test instruments, such as multimeters.

Because transistors and transistor components are generally insensitive to shock, at least of the order encountered in industrial equipment, the problem of microphonics and shortened life encountered with vacuum tubes is eliminated. Also, the low current drain and low voltages required by transistorized instruments makes battery operation of portable instruments almost as economical as power line operation.

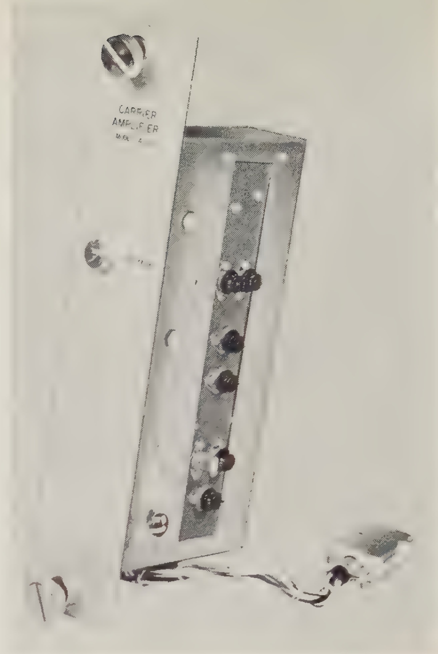

Fig. 5—The use of transistors greatly simplifies the packaging of control circuitry. The small size of the transistor reduces the size, weight, and cost of the circuitry enclosure required. Shown here is another type of enclosure used for the transistorized carrier and modulator illustrated in Fig. 4.

Transistors Have Some Disadvantages

Most of the disadvantages encountered when using transistors in industrial instruments can be attributed to their electrical characteristics. (Physically, transistors are ideally suited to almost any application.) As mentioned, thorough design and testing is very important for proper operation of transistorized circuits. Testing of the circuit should include temperature cycling over the expected range and compensation for temperature effects, if necessary.

Another disadvantage of transistors is that they are quickly damaged if the voltage or power dissipation ratings are exceeded, even if only momentarily, because of their low thermal time constant.

Summary

Correctly applied, transistor circuits will open new areas of industrial electronic instrumentation development. The construction and operational advantages of these circuits are already resulting in more trouble-free, compact and convenient equipment. As the design procedures become better established and improved components are available, the use of transistors will result in significant reductions in equipment costs.

The Application of an Analog Computer to the Study of a Tractor-Trailer Suspension System

By WALTER D. NOON
GMC Truck and
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Pitch and bounce motions generally characterize the ride of a vehicle. Previously, nearly all ride investigations were made experimentally. The development of electronic analog and digital computers, however, makes it practical to approach ride studies from an analytical viewpoint. At GMC Truck and Coach Division the analog computer is used to study vehicle dynamics problems. One of its first applications was in a study of pitch and bounce motions of a tractor-trailer combination. The first step in the study was the development of dynamic equations to describe the pitch and bounce motions. These equations were then solved on the analog computer for a range of vehicle parameters, and the effects of the parameter changes on pitch and bounce evaluated. The results of the study clearly demonstrated the feasibility of using an analog computer in ride investigations. In the future, additional degrees of freedom, non-linearities, and longitudinal effects will be considered. These studies will result in a more complete understanding of the effects of tractor-trailer parameters on ride comfort.

Using the analytical approach to vehicle dynamics problems

CONTROL, stability, and ride are vehicle dynamics problems that usually have been studied in the past by experimental methods—that is, by driving and evaluating vehicles during road tests. Testing a vehicle under actual driving conditions is indisputably authentic. There are disadvantages, however, such as the expense and time required for testing and the relatively poor control over operating conditions. The availability of electronic analog and digital computers, however, now makes it possible to study vehicle dynamics problems using analytical techniques[1]. The computers provide design engineers with equivalent information and at a saving in time and cost.

The analytical approach to a study of vehicle dynamics problems was recently expanded at the GMC Truck and Coach Division with the establishment of an analog computer program. The objective of the program is to provide design engineers with information which will aid in understanding the effect various parameters have on vehicle suspension systems—information, for example, which would be of aid to a designer having to evaluate the dynamic response of a truck to steering inputs or in selecting proper shock absorber and spring rates.

When an analytical approach is used on vehicle dynamics problems, sets of differential equations must be derived. Since the analog computer (Fig. 1) is especially well equipped to solve differential equations, its use was considered first. Additional reasons for selecting an analog computer were:

- Short programming time
- Ability to make design parameter changes and evaluate the results immediately
- Low operating cost.

Furthermore, a substantial absolute error was permissible, since comparisons were the primary interest.

Analog Computer Wired to Simulate Physical System Under Study

To understand the application of an analog computer to the solution of a problem requires an understanding of an "analog" concept. One way to illustrate this concept is to use the direct analogy that exists between a spring-mass-damper mechanical system and a resistor-capacitor-inductor electrical system (Fig. 2). The point of the analogy is that the behavior of large and expensive mechani-

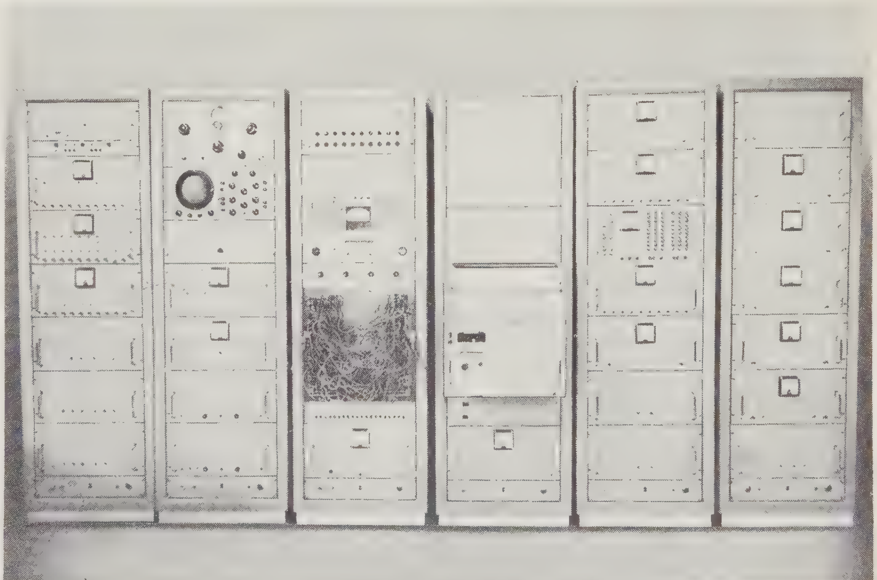


Fig. 1—This is the analog computer installation used by the GMC Truck and Coach Division to study the effects of tractor-trailer parameters on ride comfort. The computer is located at the GM Research Laboratories, GM Technical Center. The cabinets house the operational amplifiers, multipliers, function generators, recording equipment, control panel, and power supply.

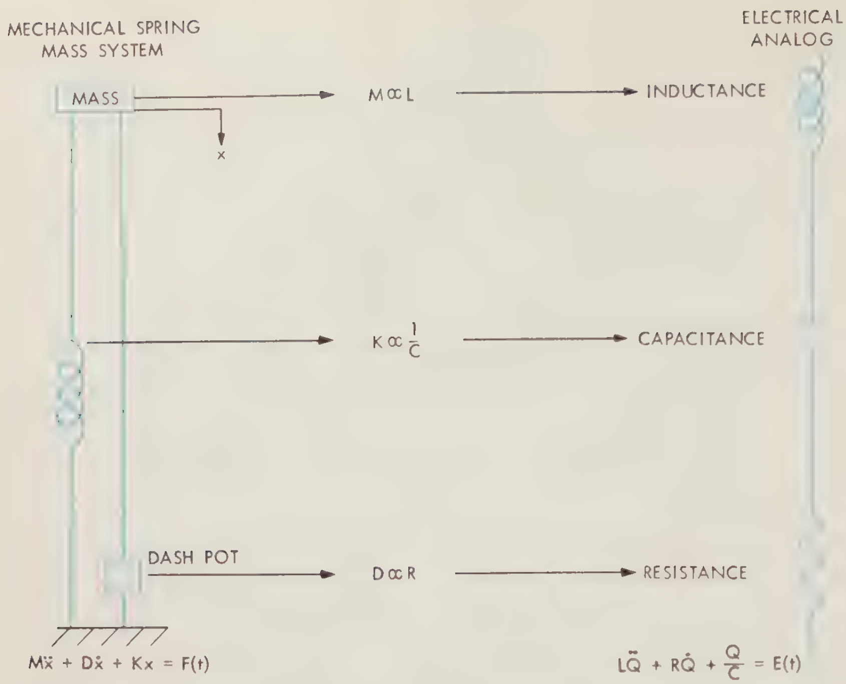


Fig. 2—A direct analogy exists between a mechanical spring-mass-damper system and an electrical resistance-capacitance-inductance system. The operation of an analog computer is based on this concept and mechanical systems can be simulated and studied by wiring simple electrical circuits and measuring the variables of interest. In the diagram shown here, the quantities $F(t)$ and $E(t)$ represent the applied force and voltage, respectively. The quantities x, $\dot{x}$, and $\ddot{x}$ are mass displacement, velocity, and acceleration, respectively. Similarly, Q, $\dot{Q}$, and $\ddot{Q}$ represent the electrical charge, rate of charge (current), and the rate of current change, respectively.

cal systems can be simulated and studied by wiring relatively simple electrical circuits and measuring the variables of interest. This is the general idea upon which the operation of the analog computer is based. Voltages are always equivalent to physical variables and the electronic components of the analog computer are wired to provide an electronic system which behaves in the same way as the physical system under study. The solutions provided by the computer are in terms of voltages proportional to the variables under study—for example, 1 volt = 10 lb or 1 volt = 2 in.

The concept of an analog computer can be clarified further by considering its primary functional components (Fig. 3), the details of which may be found in any text on analog computers[2,3]. The operational amplifier, which is the heart of the computer and its basic computing element, can be wired to act as a summer, sign changer, or integrator. Potentiometers are used to provide numerical coefficients. Electronic multipliers are used to multiply two variables. Information on other analog components, such as function generators and X-Y recorders, may be found in the literature[2,3].

Parameters of Physical System Easily Changed on Analog Computer

To illustrate how an analog computer can be wired to solve a specific equation, consider the following equation used to begin the solution of a spring-mass-damper problem on an analog computer:

$$M\ddot{x} + D\dot{x} + Kx = F(t)$$

where

M = mass
K = spring constant
D = damping coefficient
$\ddot{x} = \frac{F(t)}{M} - \left(\frac{D}{M}\right)\dot{x} - \left(\frac{K}{M}\right)x$
x = mass motion for a simple spring-mass-damper system (Fig. 4).

The equation can be solved on an analog computer as follows:

(a) Assume that $\ddot{x}$ is a known value
(b) To solve the equation, $\dot{x}$ is required. Therefore, integrate $\ddot{x}$ to obtain $\dot{x}$. (Note the sign change, Fig. 4)
(c) The solution of the equation also requires a value for x. Therefore, integrate $\dot{x}$
(d) The quantity $\ddot{x}$ is equal to the sum of $F(t)/M$, $-(D/M)\dot{x}$, and $-(K/M)x$. Therefore, use a function generator to generate $-F(t)/M$ and wire the generator as one input to a summer. (Note the sign change for a summer, Fig. 4)
(e) Multiply $-\dot{x}$ by D/M and change its sign with a sign changer
(f) Multiply $\dot{x}$ by K/M
(g) Wire $(D/M)\dot{x}$ and $(K/M)x$ as the other inputs to the summer. The output of this summer is $\ddot{x}$. This gives an electronic circuit (Fig. 4) which is analogous to a spring-mass-damper system under study.

The solution of a set of differential equations on an analog computer is merely a repeated application of this procedure.

One of the outstanding features of an analog computer is the ease with which parameters can be changed. For example, the spring constant K or the damping coefficient D can be changed by simply changing a potentiometer setting. This makes it possible to evaluate many possible design combinations in a relatively short time.

The general steps followed when solving a problem on the analog computer are as follows:

(a) Description of the problem with all pertinent information
(b) Mathematical formulation of the problem
(c) Transformation of the mathematical equations to machine equations for solution by the computer
(d) Solution of the machine equations by the analog computer
(e) Application of the results to design or analysis.

Tractor-Trailer Combination Simulated on Computer

One of the first uses of the analog computer at GMC Truck and Coach was in a study of the pitch and bounce of a tractor-trailer combination.

Description of Problem

The problem was to simulate a tractor-trailer combination on the analog computer for the purpose of providing ride data consisting of the tractor-trailer pitch and bounce response to various road inputs.

COMPONENT	SYMBOL	CIRCUIT	MATHEMATICAL OPERATION
HIGH GAIN OPERATIONAL AMPLIFIER			
OPERATIONAL AMPLIFIER USED AS A SUMMER AND SIGN CHANGER			$E_o = -\frac{R_o}{R_i}(E_1 + E_2)$
OPERATIONAL AMPLIFIER USED AS AN INTEGRATOR			$E_o = -\frac{1}{RC}\int_0^t E_i\,dt$
POTENTIOMETER ATTENUATOR			$E_o = XE_i \ (X < 1)$
ELECTRONIC MULTIPLIER (2 VARIABLES)			$E_o = -\frac{E_1E_2}{100}$
FUNCTION GENERATOR			$E_o = f(E_i)$

Fig. 3—The primary functional components of an analog computer shown here are few in number and have functions which are relatively easy to understand. Each of the primary components, for example the high gain operational amplifier, potentiometer, and electronic multiplier, is represented by a symbol. The operational amplifier can be wired to act as a summer, sign changer, or integrator. Potentiometers are used to provide numerical coefficients and electronic multipliers are used to multiply two variables.

Studies were to be made on the chassis and suspension systems utilizing axle motion inputs. Since cab mounts could be a factor in the problem, they were included in the required information. Weight and weight location information also were obtained along with the suspension and cab spring rates and damping coefficients.

To complete the description of the physical system to be studied, a schematic diagram was made of the tractor-trailer showing all important parameters (Fig. 5).

Mathematical Formulation and Transformation of Equations

One of the first steps in the mathematical formulation of the problem was to define the displacement S of the tractor, trailer, and cab springs. (In the mathematical calculations to follow, refer to Fig. 5 for a definition of all terms.) For small values of Θ_1, Θ_2, and Θ_3 let

S_1 = displacement of tractor front spring

$$S_1 = X_4 + (L + L_1)\,\Theta_1$$

S_2 = displacement of tractor rear spring

$$S_2 = X_4 - (L_2 - L)\Theta_1$$

S_3 = displacement of trailer spring

$$S_3 = X_4 - (L_4 + L_3)\,\Theta_2$$

S_4 = displacement of cab front spring

$$S_4 = X_4 + (L + L_9)\,\Theta_1 - (X_7 + L_7\,\Theta_3)$$

S_5 = displacement of cab rear spring

$$S_5 = X_4 - (L - L_{10})\,\Theta_1 - (X_7 - L_8\,\Theta_3).$$

Clockwise rotations and the upward vertical direction were considered positive. The forces in the respective springs and dampers were then represented by the following equations:

$$F_1 = K_1\,(X_1 - S_1) + C_1\,(\dot X_1 - \dot S_1)$$

$$F_2 = K_2\,(X_2 - S_2) + C_2\,(\dot X_2 - \dot S_2)$$

$$F_3 = K_3\,(X_3 - S_3) + C_3\,(\dot X_3 - \dot S_3)$$

$$F_4 = K_4\,S_4 + C_4\,\dot S_4$$

$$F_5 = K_5\,S_5 + C_5\,\dot S_5$$

where

$\dot X$ and $\dot S$ indicate differentiation with respect to time.

F = fifth wheel* force on the tractor

$-F$ = reaction on the trailer.

Newton's Laws were then applied to the three-mass system to give

$$F_1 + F_2 - F_4 - F_5 + F = M_5\,\ddot X_5 \quad (1)$$

$$F_1\,L_1 - F_2\,L_2 - F_4\,L_9 + F_5\,L_{10} - FL = M_5\,(R_5)^2\,\ddot\Theta_1 \quad (2)$$

$$-F + F_3 = M_6\,\ddot X_6 \quad (3)$$

$$-FL_4 - F_3\,L_3 = M_6\,(R_6)^2\,\ddot\Theta_2 \quad (4)$$

*The *fifth wheel,* used to attach a semi-trailer to a highway tractor, consists of a base rigidly mounted to the frame and connected through a pivot joint to a plate assembly. The plate assembly incorporates a latch mechanism used to couple or un-couple the trailer.

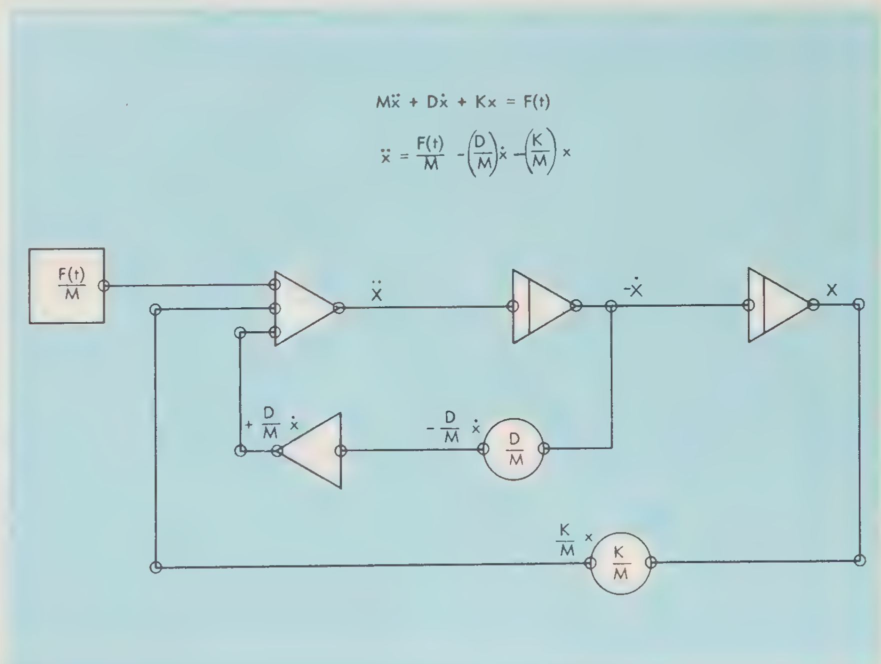
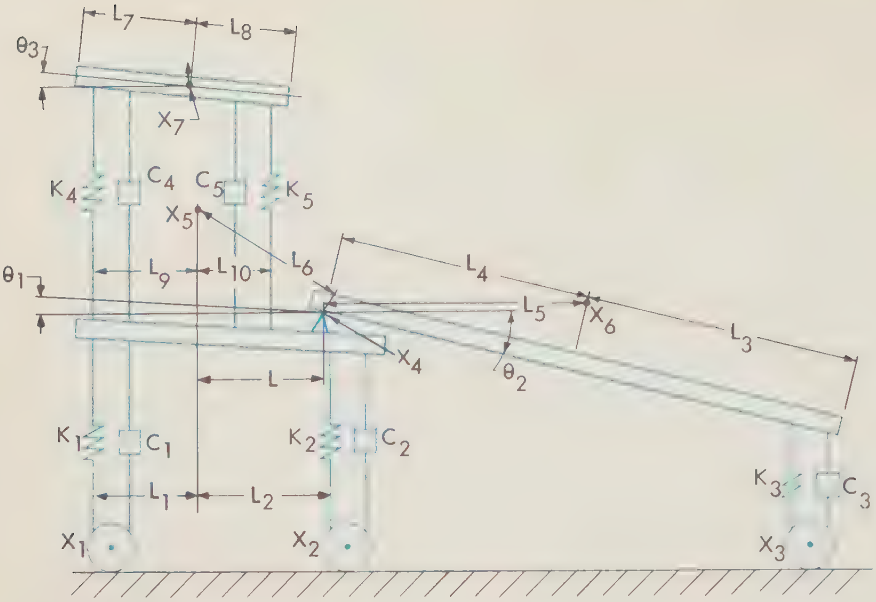


Fig. 4—This is the basic diagram used to begin the solution of the indicated equation for a spring-mass-damper problem by an analog computer. The box enclosing $-F(t)/M$ represents a function generator. The other symbols are defined in Fig. 3.



X_1 = front axle displacement

X_2 = rear axle displacement

X_3 = trailer axle displacement

X_4 = fifth wheel displacement

X_5 = tractor center of gravity displacement

X_6 = trailer center of gravity displacement

X_7 = cab center of gravity displacement

Θ_1 = tractor angular rotation

Θ_2 = trailer angular rotation

Θ_3 = cab angular rotation

K_1 = tractor front suspension spring constant

K_2 = tractor rear suspension spring constant

K_3 = trailer suspension spring constant

K_4 = front cab mount spring constant

K_5 = rear cab mount spring constant

C_1 = tractor front suspension damping coefficient

C_2 = tractor rear suspension damping coefficient

C_3 = trailer suspension damping coefficient

C_4 = front cab mount damping coefficient

C_5 = rear cab mount damping coefficient

L = perpendicular distance from tractor weight line of action to the fifth wheel location

L_1 = perpendicular distance from tractor weight line of action to the front suspension

L_2 = perpendicular distance from tractor weight line of action to the rear suspension

L_3 = perpendicular distance from trailer weight line of action to the trailer suspension

L_4 = perpendicular distance from the trailer weight line of action to the fifth wheel location

L_5 = distance from trailer center of gravity to fifth wheel location

L_6 = distance from tractor center of gravity to fifth wheel location

L_7 = perpendicular distance from cab weight line of action to front cab mount

L_8 = perpendicular distance from cab weight line of action to rear cab mount

L_9 = perpendicular distance from tractor weight line of action to front cab mount

L_{10} = perpendicular distance from tractor weight line of action to rear cab mount

Fig. 5—One of the steps required in the mathematical formulation of a problem dealing with the simulation of a tractor-trailer combination on an analog computer was to describe the physical system in diagramatic form, as indicated here. All of the parameters required for writing the necessary equations to describe the system are shown and defined.

$$F_4 + F_5 = M_7 \ddot{X}_7 \tag{5}$$

$$F_4 L_7 - F_5 L_8 = M_7 (R_7)^2 \ddot{\Theta}_3 \tag{6}$$

where

$\ddot{X}$ and $\ddot{\Theta}$ indicate the second derivative with respect to time

M_5, M_6, and M_7 = masses of tractor, trailer, and cab, respectively

R_5, R_6, and R_7 = radii of gyration of tractor, trailer, and cab, respectively.

The preceding equations were rearranged by using the following relationships:

$$\ddot{X}_6 = \ddot{X}_4 - L_5 \ddot{\Theta}_2$$

$$\ddot{X}_5 = \ddot{X}_4 + L_6 \ddot{\Theta}_1 .$$

Equation (3) was then solved for F which was substituted into equations (1), (2), and (4). Equations (2) and (4) were solved for $\ddot{\Theta}_1$ and $\ddot{\Theta}_2$, respectively, and the results substituted into equation (1). Coefficients of terms were then collected.

The equations were then transformed into machine equations suitable for solution on the analog computer, using established equation transformation techniques and associated wiring procedures[2,3].

Solution of Machine Equations

Approximately 40 operation amplifiers and 60 potentiometers were used to wire the machine equations for solution on the analog computer (Fig. 6). During subsequent stages of the problem, additional multipliers and function generators were used to simulate non-linear elements, such as shock absorbers and coulomb friction. The computer solutions to this problem were recordings of voltage versus time (Fig. 7). Bumps were fed in as axle inputs as well as various sinusoidal axle motions. The range of frequencies investigated included wheel hop frequency. Solutions were obtained for many different combinations of spring rates, shock absorber values, and fifth wheel locations.

Application of Results

The analog computer supplied the truck design engineer with information on tractor-trailer pitch and bounce for a wide range of vehicle parameters and

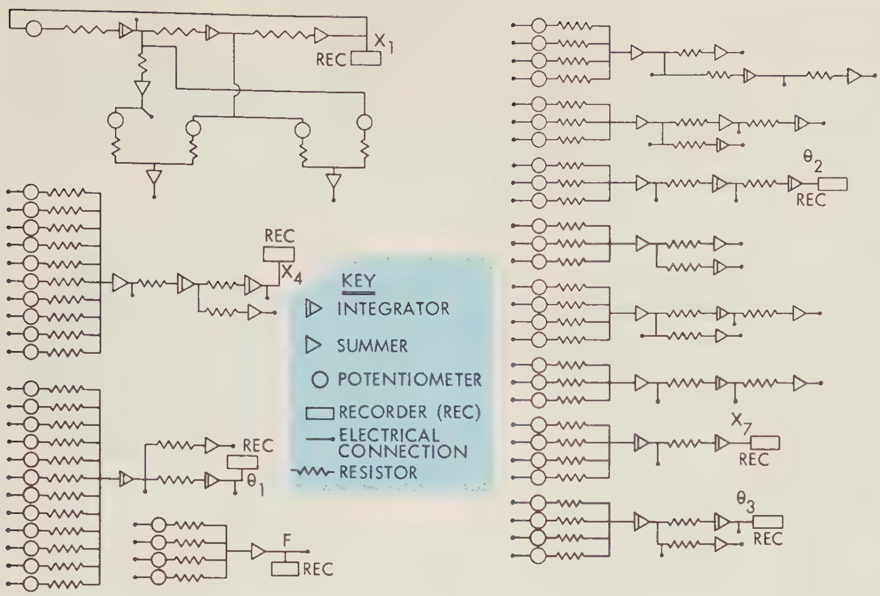


Fig. 6—This is an illustration of the wiring diagram used to simulate the tractor-trailer combination on the analog computer. The circuit shown at the upper left was used to generate sinusoidal inputs, while the remaining circuits solved equations of motion. Approximately 40 operational amplifier and 60 potentiometers were used. The X and Θ terms are defined in Fig. 5.

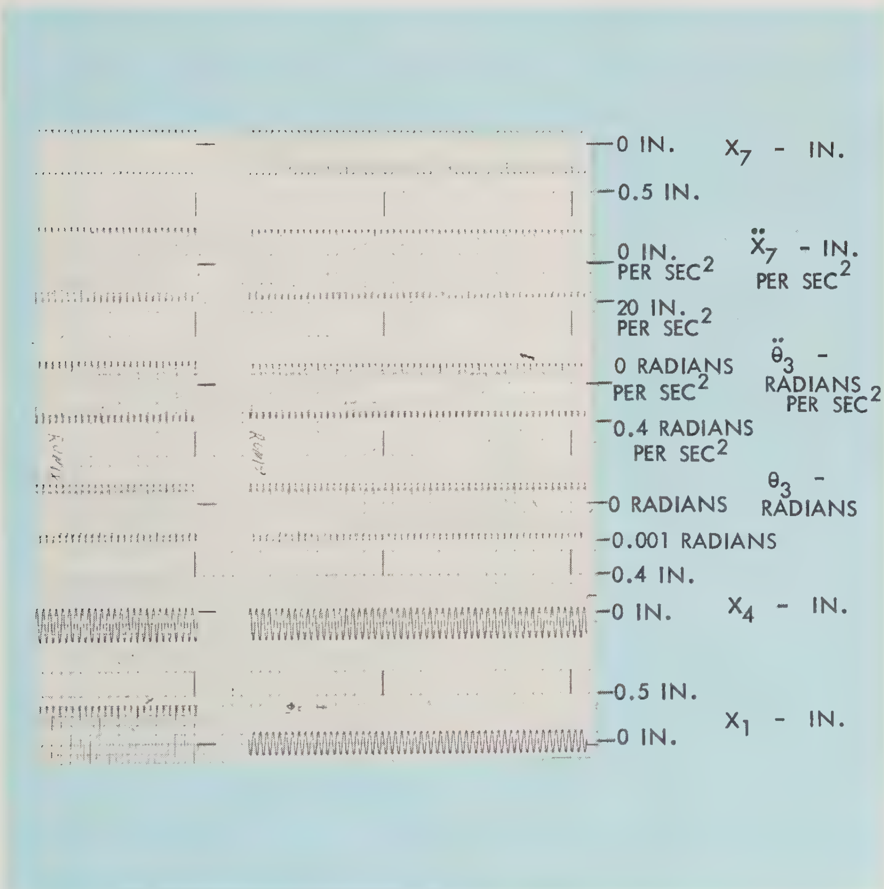


Fig. 7—This is a typical analog computer solution for a sinusoidal axle input of $X_1 = 0.125$ in. at a frequency of 1.5 cps. The solution was obtained from a voltage recorder as voltage versus time. Amplitudes of other quantities of interest at this specific axle input also are shown. Hundreds of recordings such as this were made during simulation of the tractor-trailer on the analog computer.

axle motion inputs. This information aided the engineer in analyzing the importance of various factors to a truck suspension system—for example, pitch may be more objectionable than bounce—and in deciding on the practicability of individual vehicle design changes.

The second phase of this particular problem was to verify the results obtained from the analog computer by actual tractor-trailer road tests.

Summary

Studies of relatively complex vehicle phenomena can be economically accomplished on the analog computer. The application of the computer to the solution of problems is quite straightforward, with the computer acting only as an equation solver. The mathematical formulation of equations necessary to describe the problem represents the most challenging phase of a problem's development. It is important to note, however, that the analog computer makes it possible to obtain solutions for systems of equations formerly left unsolved.

The analysis described in this paper represents only an initial step in tractor-trailer ride simulation. The ultimate goal of the analog computer program at GMC Truck and Coach is to provide the truck design engineer with an experimentally verified mathematical model of the vehicle. This will allow the engineer to change vehicle characteristics and quickly evaluate the effects of the design changes on ride using the computer. The final result will be improved truck ride through a better understanding of ride phenomena coupled with more complete investigations of possible designs.

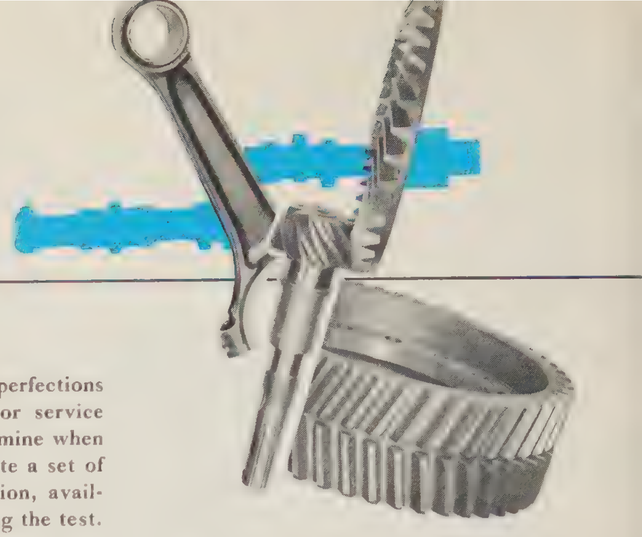
Bibliography

1. Kohr, Robert H., "The Application of Mathematics to a Basic Study of Automobile Control and Stability," *General Motors Engineering Journal*, Vol. 6, No. 2 (April-May-June 1959), pp. 14-19.

2. Korn, G. A., and Korn, T. M., *Electronic Analog Computer* (New York: McGraw-Hill Book Company, Inc., 1952).

3. Johnson, C. L., *Analog Computer Techniques* (New York: McGraw-Hill Book Company, Inc., 1956).

Applying Non-Destructive Test Standards to Improve Product Quality and Reliability



Non-destructive tests are used to find imperfections in a part or material. Imperfections may be classified according to their origin such as inherent, processing, or service imperfections. Standards for non-destructive tests are used as a guide to determine when a part or material should be accepted or rejected for production. To formulate a set of standards requires knowledge of manufacturing processes, material composition, available test equipment, and the service function of the part or material undergoing the test. The non-destructive tests used at Delco-Remy Division are examples of typical tests and their application in the automotive industry.

It is a money-wasting business to use manufacturing time and equipment to process parts that are defective from the start. This means that the manufacturer is interested in the quality of his materials or parts and is just as interested in the quality and reliability of his product when it is finally complete and ready for the user. A satisfactory means of inspection and quality control is, therefore, important to him at various stages of the manufacturing operation.

The need to measure and evaluate the quality of materials and parts has resulted in the development of non-destructive testing. Manufacturers of aircraft and ordnance equipment have used non-destructive testing methods extensively since World War II, and others have gradually stepped up their use of these methods in the intervening years.

One problem that continually faces manufacturers is interpretation and evaluation of the appearances of the test results obtained by non-destructive techniques. To help solve this problem, efforts have been made to establish workable standards for acceptance of products and materials subjected to testing. Such standards have been adopted successfully after knowledge and experience were gained in the use of non-destructive testing.

Non-Destructive Testing Explained

Non-destructive testing is done to evaluate characteristics of product quality and reliability that are considered beyond the scope of visual inspection methods. Usually, these are characteristics that could affect product performance or safety. They must meet proper standards, therefore, to avoid causing a failure.

Non-destructive tests include all investigations which determine whether a material or part has imperfections or irregularities. As the term implies, the tests themselves must not impair the function of the part or material.

The more commonly employed tests include:

- Radiography (X-ray, Cobalt-60, radioactive materials)
- Sonic tests, including sonic and ultrasonic (Fig. 1)
- Magnetic tests (magnetic particle, magnetic comparator, magnetic permeability)
- Penetrant inspection (fluorescent and dye penetrants)
- Etches for grain size or grinding burns
- Proof loads
- Thermoelectric comparisons
- Hardness tests
- Spark tests
- Chemical spot tests.

The last two tests (spark and chemical spot tests), together with the thermoelectric comparison and most of the tests based on differences in magnetic permeability, are used to segregate parts of differing material composition.

Non-destructive tests only reveal imperfections in a part, not defects. An imperfection may be defined as a fault or irregularity in a part or material. A defect is a fault or irregularity which is considered detrimental to the appearance or performance of the part or material.

For example, a slight imperfection in a part used in the automotive field might not impair its function for the intended life of the product and would be accepted for production. But the same imperfection in a part used for aeronautical purposes might be cause for rejection due to safety factors of stress and strain specified for parts required by the aircraft industry. Also, the same type of imperfection in two different parts does not mean both parts are defective since rejection depends on the size, shape, location, and frequency of the imperfection.

Classifying Imperfections According to Origin

Imperfections may be classified according to their origin such as:

- *Inherent:* resulting from melting and solidification of the materials
- *Processing:* resulting from fabrication of the finished article. Processing imperfections are further classified as:
  - (a) *Primary:* due to rolling, forging, drawing, and welding
  - (b) *Finishing:* due to grinding, heat treating, and plating
- *Service:* cracks resulting from use, the most common being fatigue cracks.

The nature of the imperfection, the type of material, or the size and shape of the part, in many cases, dictate the type

By GEORGE W. McDERMOTT
Delco-Remy
Division

An imperfection

is not always

a defect

of non-destructive test to use. In other cases, there may be a choice of one or more tests which satisfactorily reveal the imperfection. In these instances, the choice may be based upon the availability of equipment or the convenience and cost of the test method.

Inherent

Among the inherent faults usually evident in a visual examination are:

- Cold shuts in castings*
- Hot tears in castings
- Skin laminations in sheet steel
- Scabs on steel surfaces.

Inherent imperfections requiring other types of investigations are:

- Rolled out stringers of non-metallic inclusions—frequently found by magnetic particle inspection in ferromagnetic materials, or by fluorescent or dye penetrant inspection methods in non-magnetic materials when open to the surface
- Dross in castings—usually found by radiographic methods
- Porosity or gas in castings—usually found by radiographic methods
- Unsound billets—determined by ultrasonic testing.

Primary Processing

Primary processing imperfections, such as forging defects, may be found by visual examination. These are typified by such examples as a forging lap and a burned forging. On critical parts it is frequently necessary to use magnetic particle inspection, or fluorescent or dye penetrant inspection methods on non-magnetic materials, to locate all fine forging laps.

Other primary processing imperfections requiring additional testing include:

- Seams in bar stock—usually found by magnetic particle inspection
- Heavy inclusions in bar stock used on critical parts—usually found by magnetic particle inspection
- Cupping cracks in severely drawn bar stock or parts such as bolts—detected by ultrasonic testing and magnetic particle inspection
- Gas in welds and lack of penetration—frequently found by radiographic methods
- Internal shrink cracks and hot cracks in welds—found by either radiographic methods or by magnetic particle inspection
- Cracks from straightening and grinding—found by magnetic particle inspection.

Finish Processing

Imperfections resulting from finish processing may be evident visually if they are severe. This is true in the case of a quench crack. On critical parts it is necessary to use magnetic particle inspection to locate small quench cracks. Fluorescent or dye penetrant also can be used.

Burns resulting from grinding may be revealed by etching in a mild acid solution. If the burning is severe enough, magnetic particle inspection is used on critical parts to find grinding cracks, Similar cracks also may develop during acid cleaning or plating operations if the parts have high internal stresses prior to

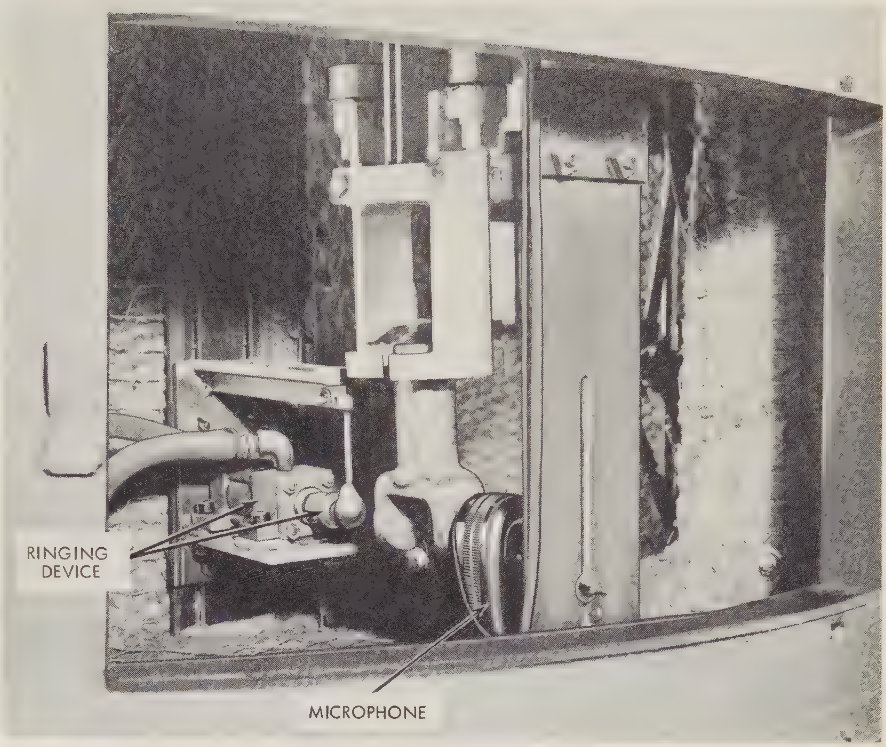


Fig. 1—An application of the sonic testing method is this machine which detects imperfections in yoke castings at Central Foundry Division of General Motors. The principle is to discriminate between the vibration frequency of an unsound casting and a sound casting when struck by a sharp blow[1]. The machine has four work stations arranged in a circle: load, ringing, "accept" unload, and "reject" unload. This photograph shows the ringing station with a yoke casting in position for test. The actuator forces the steel ball to strike the casting causing a vibration. The microphone picks up the vibration which is sent through amplifiers and frequency discriminators. Additional control equipment operates relays which cause the necessary machine actions to release the casting into either the "accept" or "reject" chute.

*For a definition of some of the terms used in the metallurgical field to identify various imperfections, please refer to the Glossary on page 36.

cleaning or plating. Magnetic particle inspection is used successfully to locate such imperfections (Fig. 2).

Service

The most common imperfection due to service operation is the fatigue crack, although some fatigue cracks may be shallow enough to permit elimination by grinding or machining. Potential fatigue cracks are rejected. This type of imperfection may be found by magnetic particle, ultrasonic, fluorescent or dye penetrant inspection methods. The method most successfully used will depend on the composition and size of the part.

testing at Delco-Remy Division is an example of an application in the automotive industry. The experience of Delco-Remy with non-destructive testing began during World War II in connection with the manufacture of equipment for military and ordnance use. Some of the appropriate techniques were carried over into the manufacture of products for civilian use. Other techniques have been added in recent years.

Magnetic particle inspection methods are used as routine procedures in testing parts that require 100 per cent non-destructive testing. They also are used as a trouble shooting tool in the permanent

Process engineers also use penetrant methods to help solve some of their more difficult molding problems.

Ultrasonic testing methods at Delco-Remy are used in a preventive maintenance program operated by the Safety Department. A typical schedule calls for:

(a) Penetrant inspection methods for all crankshafts removed from presses at overhaul to detect fatigue cracks on the surface of the shaft

(b) Ultrasonic checks to follow the penetrant inspection

(c) Penetrant and ultrasonic tests of adapter plate shanks on large

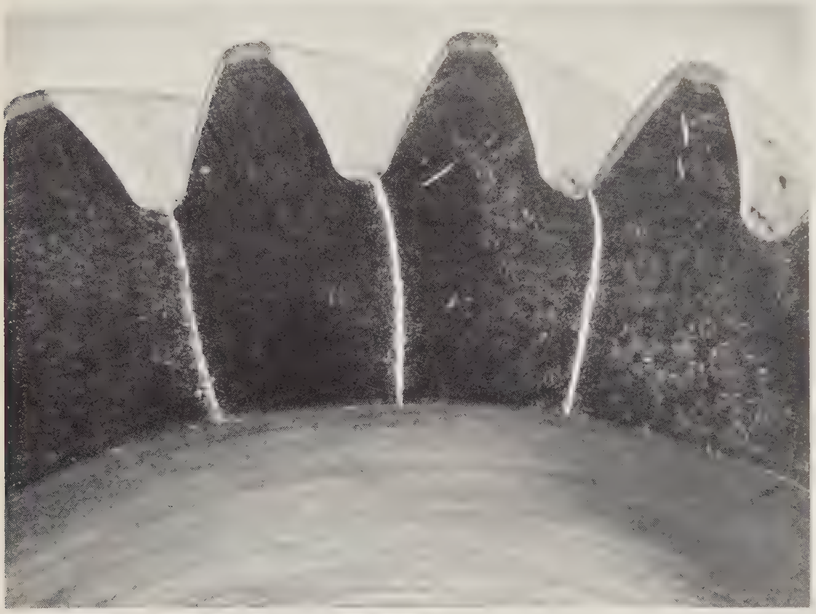


Fig. 2—Imperfections that may occur in finish processing are cracks resulting from grinding operations. These cracks may not be visible normally but they can be made to appear by non-destructive testing methods as illustrated in these two gear examples. The applications of testing methods shown are magnetic particle (left) and dye penetrant (right).

Applying Non-Destructive Tests in the Automotive Field

No single non-destructive test is applicable to every kind of material, part, or structure, nor to all their functions or operating conditions. Therefore, the selection of a non-destructive test must be based on a thorough understanding of the nature and function of the part being tested and of the condition of its services.

The non-destructive tests most commonly used in the automotive field are: magnetic particle, radiographic, ultrasonic, and penetrant.

The program for non-destructive

mold foundry for spot checking after heat treating operations.

Questionable lots of semi-finished clutch shells, pinion collars, shafts, and other steel parts machined from bar stock also are subjected to magnetic particle inspection. Cupping in cold drawn bar stock is detected successfully by longitudinal methods of magnetic particle inspection.

A wide usage of penetrant test methods on both ferrous and non-ferrous material and parts is maintained at Delco-Remy. Penetrant methods give excellent results in determining defects in molded bakelite, Nylon, and other plastic materials.

molding machines. This same approach is used to check the shaft after the aircluth has been removed from some of the large presses.

Other applications of non-destructive testing in the automotive industry are:

- Magnetic particle inspection using a-c or d-c continuous and residual methods with red, black, or fluorescent paste and black light.
- Penetrant inspection methods in routine production inspection operations on such non-ferrous automo-

tive parts as exhaust valves and pistons

- Penetrant methods in foundries
- Ultrasonic (reflectoscope) inspection as a production-inspection tool to check wall thicknesses of engine blocks where only one side is accessible to the instrument
- Sonic inspection and radiographic methods in foundry operations to detect faulty parts and maintain quality levels.

Establishing Standards for Testing

In most non-destructive tests, it is necessary to detect and evaluate flaws and defects, or to determine strength and serviceability, by indirect procedures. These predictions of strength or service performance usually involve the measurement of a different but correlated property. Therefore, a necessary prerequisite to a non-destructive test is a proven correlation between the property actually measured by the non-destructive

TYPICAL AUTOMOTIVE PARTS COVERED BY STANDARDS

Crankshafts (both forged and cast)	Exhaust Valves
Connecting Rods	Automatic Transmission Cases
Connecting Rod Nuts	Torsion Bars
Cam Shafts (both forged and cast)	Gears Used in Manual Transmission
Steering Arms	Cast Hydraulic Valve Bodies
Front Wheel Spindles	Bar Stock for Coil Springs
Front End Spindles	Hubs and Discs of Automotive Clutches
Pitman Arms	Sprags, Clutches, Gears, and Spline Teeth
Motor Blocks	Armature Shafts—Generators and Motors
Brake and Clutch Pedal Arms	Axle Shafts
Hydraulic Tappets	Clutch Shells
Master Brake Cylinder	Gear Blanks (both forged and cast)
Universal Joints (both forged and cast)	
Exhaust Valve Blanks	

Table I—A complete listing of automotive parts subject to non-destructive testing would be lengthy; however, this table identifies some of the highly stressed parts covered by standards.

TYPICAL STANDARDS FOR PARTS IN THE AUTOMOTIVE INDUSTRY

1. Surface cracks are considered detrimental and a cause for rejection. Such defects as heat-treat cracks are usually deep, always sharp, and are stress-raisers. Good process control should avoid their occurrence. Grinding checks (sharp cracks) usually mean rejection. There are, however, a few instances where grinding checks are acceptable if located where tensile stresses are low.

2. Indications of surface seams in bar stock, if of no great length or depth, are accepted if not found in highly stressed areas on highly stressed parts. Interpretations of this may differ, however.

3. Forging laps and seams, if laps will "clean up," are acceptable. Tears, flakes, and bursts are generally deep and considered serious enough for rejection.

4. Indications of subsurface defects, such as caused by cupping in cold drawn bar stocks, are cause for rejection. This particular type of primary processing imperfection usually occurs in steel that is not considered of quality subject to non-destructive testing, and is first detected by breakage of parts during machining.

5. Standards of acceptance for indications of subsurface defects such as stringers of non-metallic inclusions vary widely in the automotive industry. Generally, they are not objectionable unless found in too large a concentration, or occurring in high stress areas.

Table II—Opinions in different plants vary on the interpretation of non-destructive tests and on the establishment of a proper standard for inspection. Engineering specifications, manufacturing procedures and user requirements affect the selection of standards. In general, a typical standard for automotive parts is established as shown in this table.

test and the strength or serviceability property being predicted from measurements. Where such correlations have not been fully established, evaluations are based upon experience and judgment. This evaluation of non-destructive tests has been greatly implemented by adopting operating procedures and inspection manuals that tell the techniques to use in conducting tests and specify standards for acceptance or rejection.

The development of appropriate inspection specifications for non-destructive testing does much to reduce the need for operator decisions in this important part of inspection procedure. A proper standard is one which sets the acceptable quality level at a point where the part serves its function as required.

A question sometimes asked is how do you organize and establish a *standard* for a non-destructive test. It is not done easily or simply; however, experience shows that it requires:

- Understanding of the manufacturing processes through which a part must travel from raw material to finished part
- Knowledge of the material composition of the part
- Design intent of the product engineer
- Information on the function and use of the part in service
- Knowledge of the available testing equipment and methods
- Awareness of the limitations of the test equipment
- Improvement of the test equipment through experimentation.

In addition, metallurgical studies and static load tests in the laboratory can contribute to the establishment of standards. Sectioning and photomicrographic examination of parts showing questionable imperfections plus the results of static load tests enable qualified personnel to write a standard from which inspection employes can make decisions to accept or reject.

Table I lists some automotive parts covered by standards for non-destructive testing. A typical standard is summarized in Table II.

Conclusion

Standards, or specifications, for non-destructive testing as a means of inspection and quality control have served extensively in the aircraft and ordnance equipment industries for some time. Standards also have been used prominently in the railroad and heavy-duty truck industries in connection with both manufacturing and overhaul work. In recent years, an increasing number of applications have appeared in the automotive and related industries.

The number of automotive parts subject to non-destructive testing is small when compared to the requirements in the aircraft field. Yet, there are certain components that warrant this testing from the standpoints of safety, reliability, economy, and user demands. For example, performance and design improvements often must be accompanied by reductions in size and weight. This may mean that a part will have to stand heavier loads or higher stresses, and a more thorough check of its quality is, therefore, important. Applying non-destructive testing, of course, requires knowledge of the techniques, experience, and common sense. Decisions to use and retain these techniques do not come by chance. Each one must be justified on its merit and ability to do the necessary job.

Bibliography

1. Diamond, Milton J., "The Utilization of Sonic Principles for Application to an Automatic Method of Casting Inspection," *General Motors Engineering Journal*, Vol. 3, No. 2 (March-April 1956) p. 38-42.

Glossary

Cold Shut—An imperfectly fused junction of two streams of metal in a mold, usually caused by a stoppage in the flow of metal into the mold.

Hot Tear—A fissure, or several parallel fissures, resulting from the internal fracture of the metal while in the plastic state.

Skin Laminations—Non-metallic discontinuities originating from the inherent processing state and showing on surface of sheet steel.

Scabs—Foreign material, both metallic and non-metallic, rolled into surface of metal during plastic working stage of processing.

Stringers—Inherent or accidental non-metallic inclusions in the metal from the ingot stage.

Dross—A waste product taken off metal during smelting, chiefly metallic in character and accidentally included in the molten mass as slag inclusions.

Forging Lap—Surface defects which appear like seams caused from folding over hot metal, fins, or sharp corners then rolling or forging, but not welding, them into the surfaces.

Burned Forging—Melting and oxidation of certain elements in the grain boundaries of the metal caused by extremely high temperatures in certain areas of a forging. These temperatures, to cause a burned forging, are near the melting point.

Cupping—Internal cracks, voids, or bursts inside cold drawn bar stock and wire. Causes attributed to irregular force applied in pulling the metal through reducing dies.

Planning An Extraprofessional Reading Program for Engineers

By CHARLES E. NEWMAN
General Motors Institute

Self-education in the humanistic areas is a challenge which most engineers—as well as people in other professions—strive to meet. How this is done is a matter of individual effort and performance. The problem is to expand one's knowledge and to synthesize this knowledge. Extraprofessional reading is a way to solve the problem, but sometimes it is not easy to get started with an effective program of reading. Some experiences of three imaginary engineers plus a recommended annotated bibliography suggest how to approach the selection of a list of significant books.

The need for a "whole" personality

ENGINEERS do not read—enough. But, it is obviously unjustified to put the finger on the engineering profession, since no one reads enough.

All professional people, of course, read material within their own field and probably in related areas as well. And the amount of professional material that must be read reaches staggering proportions. Therefore, a compromise usually is made, and only the most vital and immediate professional literature is read carefully and thoughtfully. The less relevant materials are examined in the form of digests, abstracts, summaries, and annotated bibliographies.

What is true for professional reading, is especially true for extraprofessional reading. A compromise also is needed in a technical person's so-called outside reading that will enable him to *know* some things in non-technical areas and at least *know about* many others.

Extraprofessional reading is an individual problem that can be solved if the professional person begins pushing back the limitations he has placed on his reading habits. The individual still sets the limits and the pace of his reading. He either erects intellectual walls to keep out the pagans and barbarians from other fields of endeavor, or sends out the scouts of the mind to discover what others are thinking and doing.

Engineers interested in broadening their reading scope can begin by making these assumptions:

(a) The engineering profession is one of several segments of society desiring post-graduate improvement in non-technical areas
(b) There are subjects outside the engineer's area of technical specialization that he should be familiar with, such as the humanistic subjects of which he usually gets only a small sampling in his college curriculum. (Conversely, a person with a humanistic background should become familiar with technology, science, and related fields.)
(c) There is no such thing as useless knowledge[1]
(d) The objective of a reading program is information or enjoyment, or both
(e) There is no end to one's education, except that accomplished by the closed mind.

Keeping these assumptions in mind, the next step is to ask the questions:

- What can I do to refresh my memory and extend my knowledge of non-technical areas?
- With what specific items can I begin to initiate my extraprofessional reading program?

There is no complete answer to these questions, just as there is no single answer. But, there are several possible directions an engineer might take to approach satisfactory answers.

The first requisite is to prepare a self-inventory containing the engineer's intellectual background and interests. This inventory should show what interests the engineer has outside his profession, how much he already knows about them, what else he wants to learn about them, and in what direction he should proceed after he has explored one area.

The second requisite is to collect materials which will enable the engineer to reach the goals established by the self-inventory.

The following hypothetical situations illustrate how three engineers—called Eric, Ormsby, and "Hardnose" MacSchnitz—might answer these questions.

Eric, the Math Whiz

It had been some time since Eric graduated with a degree in civil engineering. He had kept pace moderately well with the advances and discoveries in his field, but he found that most of the mathematics he used was cut and dried. And when he participated in a civil engineering bull session and the subject turned to mathematics, he found himself somewhat behind the younger engineers regarding history and recent developments, like iteration or theory of sets.

Eric resolved to correct his deficiency by finding out what he could about mathematics—not algebra, trigonometry, or calculus—but mathematics, period. To reorient himself, he decided he should begin with basics—like Number, for instance. He searched for background material in bookstores and libraries until he discovered a book entitled, *Number, the Language of Science*, by Tobias Dantzig. Eric knew that he should obtain more than one book so he purchased *An Introduction to Mathematics*, by Alfred North Whitehead, and *Makers of Mathematics*, by Alfred Hooper. The three books gave him a variety of approaches to the subject. Thus, if he found one book was difficult reading on a particular phase of mathematics, he could switch to another book.

Eric sensed that the pressures of his job and family would prohibit him from reading a complete book at one or even several sittings; therefore, he planned a reading program that permitted him to complete several chapters as time allowed.

This extraprofessional reading refreshed Eric's memory on mathematics, gave him background material, and provided the

foundation from which he could explore other areas of mathematics.

Poetry Helps an Engineer

For years Ormsby had been nervous, upset, and tense. He was unable to relax either at work or at home. Ormsby realized that his condition was beginning to affect his engineering career so he began searching for a cure.

One day during a lunch hour, he mentally placed his slide rule aside and began to reminisce. His thoughts turned to his high school days and the poetic descriptions of the members of his class that he wrote for the yearbook. Ormsby knew that 54 pieces of doggerel, limericks, and other forms of poetry do not make a poet, but he had been proud to be called the "Poet of the Class of '39."

He realized that his love for poetry had not diminished over the years despite the fact that his only contact with poetry since his high school experience had been a survey course in college, singing commercials, and the poetic thought-of-the-day in the daily newspaper.

Ormsby was not really conscious of what caused his disquiet until he ran across a quotation from Darwin, the English naturalist, who said that if he had a chance to live his life over, he would have made it a rule to read some poetry or listen to some music at least once a week because he believed that part of his brain had atrophied through lack of use.

Ormsby was no Darwin, but he could learn from Darwin's regret. He decided to make a serious study of poetry—if he could find where to begin. He went to the library, looked at the catalog listing the books in print, and copied down two titles: *Sound and Sense*, by Perrine and *The Poem*, by Miles. The next Thursday night, while his wife was away playing cards, Ormsby began reading the two books. He rediscovered his interest in poetry. Now, Ormsby spends every Thursday night investigating his newly found field. It has helped him relax and has improved his engineering career.

Poetry may not be the answer to every engineer's tenseness and anxiety, but as Ormsby proved, poetry and engineering do mix.

"Hardnose" MacSchnitz

There is nothing like resolution, and MacSchnitz was a resolute individual. He was sure in his own mind that the matters which concerned him personally and professionally were tangibles—nothing abstract or irrational but just plain old hard scientific and engineering facts. He worked with objects, labored with only what was probable and with what could be verified by the senses. There was utterly no nonsense about him. He worshipped concreteness.

The beauty of the closed mind at work is far from being a joy forever. It is characterized by what it ignores—what trees it deliberately sees to miss the woods. In MacSchnitz's case, he conveniently disregarded certain principles which are fundamental to all of the practical courses he took in college and in post-graduate classes. Even to consider them would force his mind to a greater realization of his position in the world and he was absolutely resolved to maintain his fenced-in mind; it was safer that way—for him.

MacSchnitz seemed unaware of the two fundamental (maybe even improbable) assumptions upon which the whole structure of science is based: (1) that the universe operates according to certain physical or natural laws, and (2) that the mind of man can discover, formulate, and systematize these laws. So he went confidently on his way with his answers and never once doubted the mental security he had achieved. The indirectness of his use of scientific techniques, the second-handedness of his knowledge, the existence of the undiscovered outside his office—all of these did not exist for him.

No question about it, MacSchnitz was a "hardnose," and he was doing himself and his associates irreparable harm by his attitude. His refusal to develop a curiosity about the world around him, particularly the world of the intellect, was destroying his effectiveness. He was allowing his intellect to atrophy, to become a routine instrument. Although he denied it, because *intellectual* is a dirty word in some places, MacSchnitz was an intellectual or else he couldn't be successful in his profession.

But a change came over MacSchnitz when his children began studying science in high school. As they began to ask questions about the things they were studying in their science classes, MacSchnitz began to share with them the pleasure of his first discovery of science. Gradually, his mind became unsettled and he began to doubt the validity of some of his concrete opinions.

He obtained the book, *The Simplicity of Science*, a simply written fundamental book for young people interested in science which reviews the basic assumptions and primary techniques of the scientific method. After reading it, he obtained other books which discuss the various fields of science, recent scientific advances, and speculations for the future such as Bohr's *Atomic Physics and Human Knowledge* and Feigl and Brodbeck's *Readings in the Philosophy of Science*. The latter, which contains challenging selections difficult for the lay reader, proved rewarding to MacSchnitz due to his scientific background.

MacSchnitz's rediscovery of the many fields of science aroused his intellectual curiosity. As his children progressed through high school and later college, he seized the opportunity to give them assists in other fields such as music, history, and literature. By breaking out of his former narrow intellectual world, MacSchnitz broadened his interests and came closer to his children.

Summary

These three examples suggest the improvements that can be accomplished when an engineer develops his ability to synthesize[2], to combine the many segments of his knowledge into one "whole" or complete personality.

Engineers, and other professional people, too, should not limit their reading pursuits but expand them. While the frontiers of geographical exploration have almost vanished, the frontiers of the mind remain limitless. There is a vast area of reading in which professional people can rummage around, as suggested by the annotated bibliography which follows. This bibliography is unconventional. Obviously, it is not exhaustive. It is merely a sampler to give some direction and guidance to an extraprofessional reading program. Any one reading most of the selections within a year or so is on the path to becoming a well-read individual.

Bibliography

1. Flexner, Abraham, "The Usefulness of Useless Knowledge," *Harper's*, (October, 1939). Reprinted in *The Pursuit of Learning*, (New York: Harcourt Brace and Co., Inc., 1956), pp. 397-407.
2. Cross, Hardy, *Engineers and Ivory Towers*, (New York: McGraw-Hill Book Co., Inc., 1952), p. 39.

Annotated Bibliography

The publishing dates of most of the following books have been omitted since they are available currently as paperback editions.

The Non-Material Side

CHILDS, MARQUIS W. and CATER, DOUGLAS, *Ethics in a Business Society* (New York: Mentor, New American Library). Based on a study undertaken by The National Council of Churches of Christ. The authors have drawn from many individual studies both published and unpublished. Discusses the nature of moral values in our society.

DURANT, WILL, *The Story of Philosophy* (New York: Pocket Books, Inc., 1952). This endurable summary, first published in 1926, is invaluable for a quick look at the great philosophers of Western European civilization. The scholastic philosophers are omitted, as well as the great Hindu and Chinese thinkers. The author frankly admits these omissions. There is plenty of information here for most readers who desire a knowledge of certain philosophies or a background for the serious study of philosophy.

JAMES, WILLIAM, *The Varieties of Religious Experience* (New York: Mentor, New American Library). A series of lectures delivered at the University of Edinburgh about the turn of the century. Still a classic, representing the psychological approach to understanding the religious experience.

HUXLEY, JULIAN, *Man in the Modern World* (New York: Mentor, 1944). One of the world's leading scientists comments upon the human situation in the 20th century. Interesting essays include, "Science, Natural and Social," "Religion as an Objective Problem," and "Climate and Human History."

ROUSE, W. H. D., *Great Dialogues of Plato* (New York: Mentor). Everyone who considers himself "educated" should know the following: *Apology*, *Phaedo*, *Symposium*, and *The Republic*.

SCHWEITZER, ALBERT, *Out of My Life and Thought* (New York: Mentor). Describes the life of the great musician, philosopher, humanitarian, doctor.

SHAW, BERNARD, *Nine Plays* (New York: Dodd, Mead, & Co., 1947). Shaw's plays are good theatre, amusing reading. One may not always agree with Shaw, but one should be familiar with this great playwright.

Where We Are Now and How Come

ALLEN, FREDERICK LEWIS, *Only Yesterday* (New York: Bantam Books, 1946). A fascinating biography of the Roaring Twenties. Most people over 40 recall both pleasantly and unpleasantly this stage of American culture. This book has a companion piece, *Since Yesterday*, dealing with the Thirties.

BULLOCK, ALAN, *Hitler, A Study in Tyranny*, (abridged) (New York: Bantam Books). Can be profitably read along with Plato's discussion of the origin of the tyrannic man in *The Republic*. They're complementary.

CHASE, STUART, *The Tyranny of Words* (New York: Harvest Books, Harcourt, Brace and Co.). Recommends a semantic discipline to prevent abuse of the Queen's English. Still has a good deal of relevance to us today—about 20 years after its first publication.

MILOSZ, CZESLAW, *The Captive Mind* (New York: Vintage Books, 1955). Based on the experiences of the author and his observation of two dictatorships—what they do to individuals. Contains case histories and a very interesting chapter called "Ketman": Role-playing among the Communists.

MULLER, HERBERT J., *The Uses of the Past* (New York: Mentor, New American Library). An interesting study of several ancient civilizations. Very well written. Questions: "Can we make *use* of our knowledge of the past? Can we learn from history?"

ORWELL, GEORGE, *A Collection of Essays by George Orwell* (Garden City, N. Y.: Anchor Books). Contains several important essays: "Shooting an Elephant," "Politics and the English Language."

PARES, BERNARD, *Russia* (New York: Mentor, New American Library). Still one of the best short histories of Russia.

TABORI, PAUL, *The Natural Science of Stupidity* (Chilton, 1959). A review of the beliefs, folkways, mores, and fads, which were later proven to be groundless and incorrect. They were of sufficient influence, however, to slow up intellectual progress.

Science and Society, or On Beyond the Test Tube

BECK, STANLEY D., *The Simplicity of Science* (Garden City, N. Y.: Doubleday and Co., Inc., 1959).

CONANT, JAMES B., *On Understanding Science* (New York: Mentor). Discusses several famous scientists and how they arrived at an answer to their problems. Insists that everyone should have an understanding and appreciation of science's role in our society, that is to say, in our lives.

CROSS, HARDY, *Engineers and Ivory Towers*, editor, Robert C. Goodpasture. (New York: McGraw-Hill Book Co., Inc., 1952). Engineers are more humanistic than scientists. Ability to synthesize, p. 39.

DANTZIG, TOBIAS, *Number, The Language of Science* (Garden City, N. Y.: Anchor Books).

FEIGL, HERBERT and BRODBECK, MAY, *Readings in the Philosophy of Science* (New York: Appleton-Crofts, Inc., 1953).

GARDNER, MARTIN, editor, *Great Essays in Science* (New York: Pocket Books, Inc.). Significant writings by great scientists and others on various aspects of science.

JEANS, SIR JAMES, *The Growth of Physical Science* (Greenwich, Conn.: Premier Books, Fawcett Publications). Review of physical sciences from Babylonian mathematics to current (1949) atomic structures. Reader needs good basic scientific training. Very readable.

RYAN, LAWRENCE V., *A Science Reader* (Rinehart, 1959). While designed primarily for courses in scientific writing, this book contains valuable material for those who merely want to read some scientific essays.

SHAMOS, MORRIS H., *Great Experiments in Physics* (New York: Henry Holt and Co., 1959). Sound knowledge of physics and mathematics needed from Chapter 19 on.

SIMPSON, GEORGE GAYLORD, *The Meaning of Evolution*, revised edition, (New York: Mentor, 1956). Reviews simply and interestingly the evolution of man as well as other animals. Sets forth the evolutionary hypothesis.

STANDEN, ANTHONY, *Science Is a Sacred Cow* (Dutton Everyman Paperbacks). Amusing, satirical comment upon various branches of science. Lampoons snobbery and pomposity among scientists.

THRUELSEN, RICHARD and KOBLER, JOHN, *Adventures of the Mind*, from *The Saturday Evening Post* (New York: Alfred A. Knopf, 1959). Timely comments by

leading scholars, scientists, and thinkers, including Edith Hamilton, Paul Tillich, Jacques Barzun, Lewis Mumford, Walter Gropius, and Bertrand Russell.

WHITEHEAD, ALFRED NORTH, *Science in the Modern World* (New York: Mentor, 1948).

Experience with Drama

CHUTE, MARCHETTE, *Shakespeare of London* (Dutton Everyman Paperbacks). Best summary of what is known about Shakespeare and the London which he knew.

HARRISON, G. B., *Introducing Shakespeare* (New York: Mentor, 1949). A very readable little book. Good place to begin in reviewing Shakespeare and his plays.

.... *Six Great Modern Plays* (New York: Dell Books, 1956).

WATSON, E. BRADLEE and PRESSEY, BENFIELD, *Contemporary Drama: 9 Plays*, *Contemporary Drama: 11 Plays*, *Contemporary Drama: 15 Plays*. (New York: Charles Scribner's Sons). 15 plus 11 plus 9 plus 6 (above) equals 41 plays. A pretty good start in reading modern plays.

Concentrated Language

CIARDI, JOHN, *How Does a Poem Mean?* (Boston: Houghton, Mifflin Co., to be published in 1960). This work is written in a lucid and fascinating manner, and restores poetry to its proper place in one's personal life.

MILES, JOSEPHINE, *The Poem: A Critical Anthology* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1959). Contains many representative poems. Well written and helpful for those beginning a serious study of poetry.

PERRINE, LAWRENCE, *Sound and Sense, An Introduction to Poetry* (New York: Harcourt, Brace and Co.). Also a good text with which to begin or resume the study of poetry. Lucid explanations and interpretations.

Brief Candles, Some of Which Burn a Long Time

CRANE, MILTON, editor, *50 Great Short Stories* (New York: Bantam Books, 1952). This volume and the following two contain a great variety of subjects and ideas with which storytellers have concerned themselves since the middle of the nineteenth century.

SPEARE, M. E., editor, *The Pocket Book of Short Stories* (New York: Pocket Books, Inc., 1952). Superb selection but needs to be brought up to date.

WARREN, ROBERT PENN and ERSKINE, ALBERT, editors, *Short Story Masterpieces*, (New York: Dell Books). A sample of 36 stories, all modern.

Music, Music, Music

McSPADDEN, J. WALTER, *Operas and Musical Comedies* (New York: Thomas W. Crowell Co., 1954).

O'CONNELL, CHARLES, *The Victor Book of Symphonies* (New York: Simon and Schuster, 1948).

SIEGMEISTER, ELIE, *The Music Lover's Handbook* (New York: William Morrow and Co., 1943).

There are many sources to help develop an appreciation and knowledge of music. These three just happen to be particularly useful for reference.

Why is an Artist?

CLARK, KENNETH, *The Nude* (Garden City, N. Y.: Anchor Books, 1959). The augmented A. W. Mellon lectures, discussing the aesthetic theory of the representation of the human nude throughout history.

MAUGHAM, W. SOMERSET, *Moon and Sixpence* (New York: Modern Library, Random House, Inc.). Novel based on the life of Gaugin.

MYERS, BERNARD, *50 Great Artists* (New York: Bantam Books). Good sampling.

.... *Pocket Library of Great Art* (New York: Harry N. Abrams, Inc.). Published at various times. Text and reproductions—50 pages, 30 in color. This is a major achievement, bringing famous painters and their work to the general public at a reasonable price.

STONE, IRVING, *Lust for Life* (New York: Pocket Books, Inc.). Fascinating biography of Van Gogh.

VASARI, GIORGIO, Introduction by Alfred Werner, *Lives of the Artists* (New York: Noonday Press). Biographies of many great artists of the Renaissance.

Two Epics and One Reference

DANTE, *Hell*, Translator and editor, Dorothy L. Sayers (Baltimore: Penguin Books). Excellent translation. Copious notes and commentary to aid the modern reader of this greatest book of the Renaissance.

HOMER, *The Odyssey*, Translator, E. V. Rieu, (Baltimore: Penguin Books).

GRAVES, ROBERT, Translator, *The Greek Myths*, 2 volumes (Baltimore: Penguin Books). A retelling of the myths upon which much literature and literary allusion are based.

Author-to-Reader Relationship

ASCH, SHOLEM, *The Nazarene* (New York: G. P. Putnam's Sons, 1939). A novel based on the life of Jesus and the society of that time.

FIELDING, HENRY, *Tom Jones* (New York: Modern Library, Random House, Inc., 1950). First great modern novel. Satirical, picaresque, amusing.

HUXLEY, ALDOUS, *Brave New World* (New York: Bantam Books). A novel which projects what future society might be like, based on present technical knowledge.

KOESTLER, ARTHUR, *Darkness at Noon* (New York: Signet Books, The New American Library).

MARQUAND, JOHN P., *The Late George Apley*, (New York: Pocket Books, Inc.). One of the best American novels of manners. Beats his *Wickford Point* only by a hair.

MAUGHAM, W. SOMERSET, *Of Human Bondage* (New York: Modern Library, Random House, Inc.). Classic narrative of a boy's education, maturity, and final resolution. Largely autobiographical.

ORWELL, GEORGE, *1984* (New York: Signet). A novel which extends some present tyrannies to include the entire world by 1984 and describes the conditions which might result.

VOLTAIRE, *Candide*, Translator, John Butt (Baltimore: Penguin Books). Almost everything satirized.

WALTARI, MIKA, *The Egyptian* (New York: G. P. Putnam's Sons, 1949). The odyssey of an Egyptian physician in and around the Middle East 14 centuries before Christ.

WARREN, ROBERT PENN, *All the King's Men* (New York: Bantam Books). Rise and fall of a Southern political demagogue. Shows how dictatorship could happen here.

A Patent Problem Deriving from Machine Maintenance

By BRYCE BEECHER
Patent Section
Detroit Office

What is *repair* and what is *reconstruction?*

As brought out in previous articles, the patent grant confers the right to exclude others from making, using or selling the invention to which the patent is directed. When one purchases a patented machine he, of course, obtains an implied license to use the machine; also he obtains the right to dispose of it, as by resale, should the time arrive when he has no further need of it. Additionally, a purchaser of a patented machine is permitted to make reasonable repairs as necessary to keep the machine in working order. The right to use and to repair, however, in the absence of an express agreement does not include the right to *reconstruct*, for the implied license attaching to the purchase does not include a license to *make* the machine. Thus, if the purchaser reconstructs the machine, he becomes liable in damages to the patentee and subject to being enjoined from using the machine further. The motivation of the complaining patentee in such a case is, of course, the loss of a sale or other material gain or benefit, as compensation for services under a rebuilding contract. If the loss is a sale it may go to the entire machine or it may go to a sub-assembly or a component part of a sub-assembly.

On the foregoing, it should be clear that considerable importance attaches to the question: What is a *repair* and what is *reconstruction?*

Let it be supposed, for example, that a purchasing agent for a manufacturing company using a large number of patented cutting machines is presented by the works manager with a requisition calling for several hundred expensive shaft coupling assemblies of special design to be substituted for like assemblies in these machines. It will be assumed that the assemblies to be replaced have developed an undesirable amount of lash and that each assembly comprises suitable fixtures whereby the coupling parts are joined to the shaft sections. On inquiry, the purchasing agent finds that he can effect an appreciable saving by purchasing the assemblies from the XYZ company rather than from the company from whom the patented machines were obtained. Assuming the involved patent is valid and that the claims thereof recite the coupling assembly, whether he is free to place the business with the XYZ company, of course, hinges on whether the installation of the new assemblies would amount to a permissible repair or to a rebuilding of the machines and, hence, to an infringement of the patent—rendering his company subject to suit. What is the proper decision in this situation?

Perusal of Court decisions in point of the question of what acts constitute repair and what acts constitute reconstruction compels the conclusion that there is no pat answer, which is to say that in a given case the answer to the question depends on the particular facts and circumstances of the case. The act usually at issue, as perhaps suggested above, is the replacement by the purchaser of one or more parts of the machine which have become lost, broken, damaged or worn out. Occasionally, however, the inquiry goes to the propriety of an alteration made in the machine by the purchaser to adapt it for work not in contemplation at the time the machine was purchased.

Fortunately, the Court decisions do provide certain guides useful to one charged with making a decision in a situation such as the hypothetical one above. It is established, as would be expected, that if the replacement part is not a component of the combination to which the patent claims* are addressed, the purchaser cannot be held to have stepped beyond his implied license. But here, in fact in all cases, one should be careful that the replacement part is not per se the subject of a patent. It is further established that where the part replaced by the purchaser, although a component of the patented combination, is one which by the nature of the machine and the work it does becomes worn out after limited use (for example, the knives of a patented planing machine), the purchaser cannot be held guilty of transgressing on the rights of the patentee. In the planing machine case, the Court referred to the knives as being the "ultimate tool" of the invention, "liable to be often worn out or to become inoperative with respect to their intended effect." The Court also attached importance to the fact that the patentee surely contemplated that it would be necessary to replace the knives at frequent intervals.

In another significant case, in which the patent concerned an axle† construction, the decision of the Court turned on the fact that the parts not replaced by the purchaser so dominated the overall construction that the substitution could not be considered a rebuilding. In other words, in the opinion of the particular Court the rule or test to be applied is the test of dominance,—that is, if the substituted parts dominate the structure after their installation, then the purchaser of the machine is liable for infringement. This test obviously leaves much to be desired since it is often difficult to decide with any assurance which of the two sets of parts, that is the replaced parts and those not replaced, dominates the construction. The test of the planing machine case is much more definite, but, unfortunately, not applicable to all situations.

Where it is clear that the patentee is using his machine patent solely or primarily as a device to further the sale of an item not of itself the subject of a patent, although recited in the claims of the machine patent, a purchaser of the machine obtaining his requirements of the item from a supplier other than the holder of the machine patent cannot be held as an infringer, irrespective of any question of permissible repair or reconstruction. This was not always true. Thus, in a case decided in the early days of the phonograph, it was held that a manufacturer holding a phonograph pat-

*The claims of a patent determine the extent of the patentee's monopoly. A claim to a machine or other assemblage recites the several parts thereof which in combination represents the invention. The claim further recites the relationship of these parts to one another. Normally, a patented machine includes parts not involved in the invention and not recited in the patent claim.

†Many of the cases do not concern machines in the strict sense of the word, but they are nevertheless applicable to situations involving machines.

Notes About Inventions and Inventors

Contributed by
Patent Section
Detroit Office

The following is a general listing of patents granted in the names of General Motors employes during the period October 1, 1959 through December 31, 1959.

AC Spark Plug Division
Flint, Michigan

• **Leonard F. Stewart,** (*B.M.E., General Motors Institute, 1953*) project engineer, inventor in patent 2,908,488 for a variable venturi.

• **Ralph O. Helgeby,** (*M.E. degree, Horton School of Technology, Norway, and General Motors Institute*) staff engineer, inventor in

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Continued from page 41

ent reciting the phonograph record in several claims as part of the inventive combination had a valid cause of action against another manufacturer who was supplying records fitting the machine. This decision was overruled by a number of later decisions, including a decision in a case wherein the patent involved was addressed to a domestic heating system incorporating a switch device operating to prevent loss of the flame in the furnace during mild weather. The device, like the phonograph record, though unpatented of itself, was recited in the claims of the patent as a component of the system. It being established to the satisfaction of the Court that the manufacturer of the switch device was using the patent primarily to further the sale of the switch device, the Court decided in favor of the alleged infringer.

Consistent with the case just discussed, it has been held that the manufacturer of a dispensing or vending machine cannot properly use his patent on the machine to promote the sale of the article dispensed thereby.

The right to replace an "ultimate tool," such as a knife or bit, capable only of limited use, may not include the right to replace parts directly associated therewith. In other words, depending on the facts of the case, it might be held improper for the machine purchaser as a matter of convenience to replace the holder for the tool as well as the tool itself. In the decision which could be contended as controlling in this situation, the patents at issue involved an automobile ignition timing device. The device included a circuit breaker assembly comprising a pivoted arm carrying an electric contact member that cooperated with another contact member to periodically make and break the ignition circuit. These contact points were subject to considerable wear and required frequent replacement, possible without replacing also the pivoted arm. To simplify the making of the replacement, the defendant in the case customarily replaced the arm as well as the contact. It was held that this went beyond his right of repair and that he was guilty of infringement for rebuilding.

The more recent cases suggest the possibility of a trend allowing the purchaser, in general, a little more latitude in the direction of what he may do to maintain the machine or other contrivance in working order. Thus, a Court recently held that incident to replacing an abrasive stone in a stone holder, the holder being recited with the stone in the claims of the patent, it was proper for the purchaser of the honing machine to straighten bent portions of the holder and to Bonderize the same, if corroded. It is important to note, however, that in this case the inventive concept had relation to certain flanges carried by the stone holder and that the defendant proved to the satisfaction of the Court that in re-working and treating the holder he did nothing to the flanges. The defendant made a point of offering this proof because of prior decisions where the patentee was held aided in his case by the fact that the act of the purchaser, objected to by the patentee, went to the part representing the actual invention. It should be injected that not infrequently in claims of the combination type all of the parts recited are old except one, which in its relation to the old parts recited constitutes the invention.

To take up still another aspect of the repair-reconstruction problem, it is generally held that a purchaser of a patented machine infringes when he effects an actual alteration of the machine. The Courts here refer to "loss of identity" of the machine. In this, the Courts have reference to the fact that a defendant purchaser manifestly cannot contend a mere repair when the machine as altered does not accord with the original machine. In one of the controlling cases in which the Plaintiff patentee was sustained, a purchaser of a patented caramel wrapping machine modified the machine so that it would take caramels of larger size than those with respect to which the machine was originally designed. In a second case, the patent concerned an incubator. The defendant purchaser, adjudged liable, altered the purchased incubators by applying additional trays and larger ventilators, his purpose being to increase the capacity of each incubator and thereby lessen the number required.

Reverting now to the hypothetical case involving the purchasing agent and the coupling assemblies, it should be apparent that the facts and circumstances of this situation would have to be further developed before any decision based on the decided cases could be reached. Thus, for example, one would need to determine, having regard to the ignition timing device case, whether the objectionable lash could be corrected without replacing the entire coupling assembly. Additionally, and by way of further example, a careful analysis would need to be made to determine whether the machine builder could contend with any force that the coupling either predominates in the assemblage to which his patent claims are directed or constitutes the essence of his invention.

Since litigation, particularly unsuccessful litigation, is expensive, it manifestly would be incumbent on the purchasing agent to solicit the opinion of the company patent counsel in the matter. Often an item of fact, appearing insignificant to the layman, may, in its relation to the overall picture, dictate the correct answer to such a problem.

patent 2,909,365 for speedometer apparatus.

• **Wesley W. McMullen,** (*B.S.M.E., University of Michigan, 1934*) staff engineer, inventor in patent 2,911,693 for a spring clip fastener.

• **Gordon W. Harry,** (*B.S.M.E., University of Michigan, 1923*) staff engineer, inventor in patent 2,912,254 for an air suspension system with automatic low pressure circuit cutoff.

• **Paul H. Kehm,** (*B.S.E.E., University of Illinois, 1950*) senior project engineer, and **Werner F. Schultz,** (*B.E.E., University of Detroit, 1938*) development engineer, inventors in patent 2,912,595 for an electric fuel pump system.

• **John E. Schultz,** (*B.S.E.E., Purdue University, 1938*) director, advanced systems, Research Development, Milwaukee plant, inventor in patent 2,912,639 for a microsyn amplifier.

• **John A. Whaley,** (*General Motors Institute*) research engineer, inventor in patent 2,913,659 for a testing device for spark plugs.

• **Earl M. Brohl,** special assignment, inventor in patent 2,917,110 for a vapor lock preventing device.

• **Donald B. Lewis,** (*Northwestern University and B.S.E.E., Marquette University, 1949*) project engineer, inventor in patent 2,918,138 for a disposable and cleanable filter.

• **Argyle G. Lautzenhiser,** (*B.S.E.E., Tri-State College, 1940*) senior project engineer, inventor in patent 2,907,979 for a direction signal.

• **Charles G. Gibson,** (*Lawrence Institute of Technology*), now a layout man, GM Engineering Staff, inventor in patent 2,907,247 for a sighting device.

Allison Division
Indianapolis, Indiana

• **Wilgus S. Broffitt,** (*B.S.M.E., University of Kentucky, 1938*) head, Design Group, inventor in patent 2,907,233 for a mechanism for inspecting and establishing machining location points on a workpiece.

• **Leonard J. Schmid,** (*B.S. Met. E., South Dakota School of Mines and Technology, 1942*) senior experimental metallurgist, inventor in patent 2,908,056 for manufacture of bearings.

• **Howard W. Christenson,** (*B.S., Oregon State College, 1938*) head, research department; **Mark E. Fisher,** (*B.S.M.E., Purdue University, 1947*) senior project engineer; and **Raymond J. Maci,** (*B.S.M.E., Illinois Institute of Technology, 1935*) supervisor, ordnance design, Transmission Development, inventor in patent 2,912,884 for a transmission.

• **Howard W. Christenson***, inventor in patent 2,916,999 for a variable discharge vane pump.

Aeroproducts Operations
Allison Division
Vandalia, Ohio

• **William A. Weis,** (*B.M.E., University of Dayton, 1938*) senior designer, inventor in patent 2,910,091 for a peripheral metering distributor valve.

• **Roy C. Bodem,** (*University of Dayton*) designer, inventor in patent 2,910,966 for an actuator seal assembly.

• **Howard M. Geyer,** (*B.S.I.E., University of Alabama, 1940*) chief research engineer, and **James W. Light,** (*Miami University and The Ohio State University*) experimental engineer, inventors in patent 2,911,844 for an actuator with load feedback means.

• **Alan B. Blackburn,** (*Marietta College and The Ohio State University*) experimental engineer, inventor in patent 2,912,008 for a valve actuating means.

• **Kenneth L. Berninger,** (*Purdue University*) senior project engineer; **Robert K. Skinner,** (*B.S.E.E., University of Cincinnati, 1943*) senior project engineer; and **Calvin C. Covert,** (*B.S.M.E., University of Cincinnati, 1950*) senior engineer, inventors in patent 2,916,094 for a propeller control system.

• **Howard M. Geyer***, inventor in patents 2,918,903 for a high temperature hydraulic actuator assembly; 2,918,786 for a dual drive actuator; and 2,918,799 for a combined linear and rotary actuator.

***Inventors' names marked with an asterisk have biographical listings noted previously in this issue's Notes About Inventions and Inventors.**

• **Roy H. Brandes,** senior project engineer, and **Francis E. Conn,** project engineer, inventors in patent 2,918,129 for a propeller control system.

Buick Motor Division
Flint, Michigan

• **Frank R. L. Daley, Jr.,** (*B.S. in physical and biological science, University of Massachusetts, 1940*) staff engineer, inventor in patent 2,908,351 for a differential lubricating system.

• **Charles S. Chapman,** (*B.S.I.E., Wayne State University, 1950 and M.A.E., Chrysler Institute of Engineering, 1953*) staff engineer, and **Kenneth W. Gage,** (*General Motors Institute, and B.S.M.E., Lawrence Institute of Technology, 1941*) section engineer, inventors in patent 2,912,876 for a transmission.

• **Joseph D. Turlay,** (*B.S.M.E., Oregon State College, 1928*) director, Power Plant Activities, inventor in patent 2,914,130 for a throttle linkage mechanism.

Cadillac Motor Car Division
Detroit, Michigan

• **William E. Bell,** (*B.S.E.E., University of Kentucky*) senior project engineer, inventor in patent 2,913,589 for engine starting apparatus.

• **Ralph H. Johnson,** (*B.S.M.E., University of Washington, 1952*) senior project engineer, inventor in patent 2,916,333 for a bearing with oil reservoir.

• **Jack T. Cornillaud,** (*Henry Ford Community College*) senior special tester, inventor in patent 2,918,146 for a brake adjusting device.

Central Foundry Division
Fabricast Plant
Bedford, Indiana

• **Harold L. Benham,** (*B.S. in physics, Indiana University, 1951*) development engineer, inventor in patent 2,908,952 for a method of forming an investment mold.

Chevrolet Motor Division
Detroit, Michigan

• **Adelbert E. Kolbe,** (*University of Michigan*) assistant staff engineer, inventor in patents 2,907,309 and 2,916,020 for interior ventilation and an oil separator for an engine crankcase ventilation system, respectively.

• **Robert F. Tuttle,** senior process engineer, inventor in patent 2,907,379 for a roller type tire mounting machine.

• **William E. Brunsdon,** (*B.S.M.E., Michigan College of Mining and Technology, 1951*) research engineer; **Robert E. Denzer,** (*B.S.M.E. and M.S., The Ohio State University, 1951*) design engineer; **Robert Schilling,** (*M.E. degree, Technical University, Munich, Germany, 1922*) now with General Motors Overseas Operations Division; and Maurice Olley, retired, inventors in patent 2,908,508 for inflation control for air suspension.

• **Adelbert E. Kolbe***, and **Earl W. Rohrbacher,** (*B.S.M.E., University of Utah, 1926*) design engineer, inventors in patent 2,909,162 for an engine cooling system.

• **Vernon F. Fishtahler,** (*General Motors Institute 1940*) design engineer and **William W. Vincent,** (*University of Michigan*) senior project engineer, inventors in patent 2,910,147 for a high-low brake pedal linkage.

• **Charles W. Jackman,** (*International Correspondence School*) assistant staff engineer, inventor in patent 2,913,290 for a journal shaft bearing.

• **Joseph F. Bertsch,** (*B.S.M.E., University of Cincinnati, 1948*) design engineer; **Kai H. Hansen,** (*Lawrence Institute of Technology*) staff engineer; and **Robert Schilling***, inventors in patent 2,916,284 for an air suspension leveling valve.

Delco Appliance Division
Rochester, New York

• **Donald W. Laviana,** (*B.S.M.E., Yale University, 1944*) project engineer, inventor in patent 2,910,551 for a switch assembly.

• **Wilbur L. Carlson,** superintendent, manufacturing facilities, inventor in patent 2,913,603 for pole pieces.

• **Francis M. Ryck,** (*B.S., University of Rochester, 1950*) assistant supervisor, windshield wiper applications, inventor in patent 2,915,769 for a windshield wiper blade, and patent 2,915,771 for a windshield wiper transmission and arm assembly.

• **Eugene R. Ziegler,** (*B.E.E., University of Rochester, 1943*) design engineer, inventor in patent 2,915,772 for a windshield cleaning system.

Delco Moraine Division
Dayton, Ohio

• **Anton F. Erickson,** (*Pennsylvania State University, 1931*) assistant supervisor, brake research engineering, inventor in patent 2,908,358 for a disc brake.

• **Frederick W. Sampson,** (*M.E., Cornell University, 1924*) section engineer on special assignment, inventor in patent 2,910,145 for a brake structure.

• **Calvin J. Werner,** (*E.E., University of Cincinnati, 1930*) now vice president of General Motors and general manager of GMC Truck and Coach Division, inventor in patent 2,914,140 for a hydraulic wheel cylinder for multiple disc brake with leakage bleed-off.

Delco Products Division
Dayton, Ohio

• **Ralph K. Shewmon,** (*General Motors Institute, 1934*) assistant chief engineer, electrical products, and William G. Pontis, retired, inventors in patent 2,909,333 for a domestic appliance.

• **Elmer L. Young,** (*B.S.E.E., The Ohio State University, 1929*) senior project engineer, inventor in patent 2,910,600 for a rotor with heat radiating means.

• **George W. Jackson,** (*B.S.M.E., Purdue University, 1937*) assistant chief engineer, automotive products, and **John F. Pribonic,** (*B.S.M.E., Princeton University, 1947*) staff engineer, inventors in patent 2,918,304 for a pneumatic suspension control system.

Delco Radio Division
Kokomo, Indiana

• **Thomas H. Lee,** (*University of Akron*) senior project engineer, inventor in patent 2,911,608 for a ground spring clip.

Delco-Remy Division
Anderson, Indiana

• **Lyman A. Rice,** (*B.S.E.E., University of Utah, 1935 and M.S.E., University of Michigan, 1936*) staff engineer, inventor in patents 2,908,854 for a battery charging circuit; 2,913,641 for a regulator relay; and 2,914,713 for a tensioning device.

• **Brooks H. Short,** (*B.S.E.E., 1931 and M.S.E.E., 1934, Purdue University*) director of Advanced Engineering, inventor in patent 2,909,760 for a direction signal system.

• **Louis J. Raver,** (*B.S.M.E., Purdue University, 1947*) senior project engineer, inventor in patent 2,912,594 for a battery charging circuit.

• **James C. Norris,** (*Purdue University*) head, Ignition Section; **William E. Abel,** designer; and **Wallace C. Brown,** drafting group leader, inventors in patent 2,913,543 for an ignition device.

Detroit Diesel Engine Division
Detroit, Michigan

• **John Dickson,** (*diploma, Royal Technical College, Glasgow, Scotland*) staff engineer in charge of forward design, inventor in patent 2,909,160 for a piston.

• **Charles H. Frick,** (*B.S., Iowa State College, 1934*) senior project engineer, inventor in patent 2,916,040 for a governing device for engines.

• **Edward A. Chapin,** (*B.S. Aero. E., 1934 and M.S. Aero. E., 1935, University of Michigan*) senior project engineer, and John R. Secord, no longer with GM, inventors in patent 2,916,314 for a rotary shaft seal.

• **Francis R. Moore,** (*B.S.M.E., Michigan State University, 1929*) senior contact engineer, inventor in patent 2,918,207 for a turbocharger.

Detroit Transmission Division
Ypsilanti, Michigan

• **Richard L. Thorman,** (*General Motors Institute, 1935*) senior project engineer, inventor in patent 2,910,942 for a fluid pressure supply system.

• **Darrel R. Sand**, (*B.M.E., General Motors Institute, 1949*) assistant staff engineer, inventor in patent 2,911,853 for a transmission.

• **Forrest R. Cheek**, (*B.S.M.E., University of Illinois, 1946*) senior project engineer, inventor in patent 2,916,881 for a controlled fluid coupling.

Electro-Motive Division
La Grange, Illinois

• **C. Hugo Patrie**, (*B.S.M.E., University of Dayton, 1936*) senior designer and John Markestein, deceased, inventors in patent 2,907,283 for railway vehicle suspension.

• **Torsten O. Lillquist**, electrical research engineer, inventor in patent 2,907,892 for a power train control.

• **Lauren L. Johnson**, (*B.S.E.E., University of Nebraska, 1938*) electrical control development engineer, and **Benjamin C. Liebenthal**, (*B.S.E.E., University of Wisconsin, 1949*) senior project engineer, inventor in patent 2,907,941 for a series compound motor circuit.

• **William F. Holin**, (*M.E., Konstanz, Germany*) senior project engineer, inventor in patent 2,911,073 for a brake rigging stabilizer.

• **Walter S. Rzemienski**, senior process engineer, inventor in patent 2,911,131 for a paper packet processing machine.

• **William R. Foit**, senior designer, and **Robert H. Wellman**, (*B.S.M.E., Northwestern University*) mechanical design engineer, inventors in patent 2,916,026 for air intake for free piston engines.

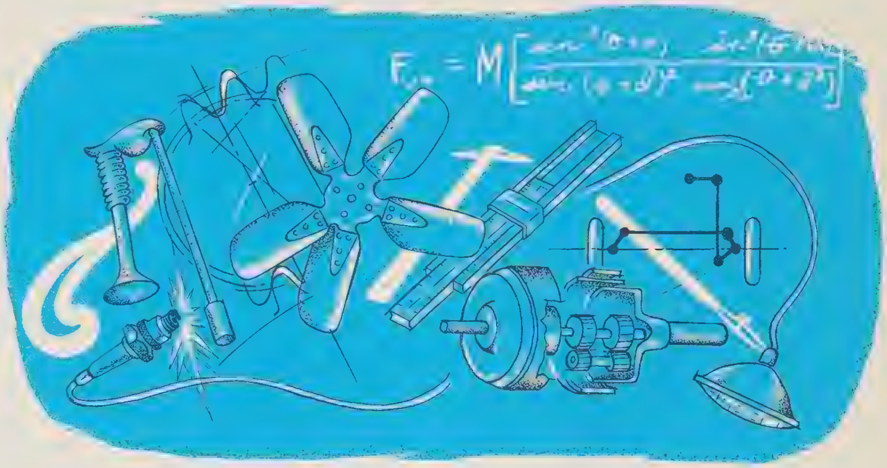
GM Engineering Staff
Warren, Michigan

• **Gilbert K. Hause**, engineer in charge, Transmission Development Group, inventor in patent 2,908,190 for a transmission.

Oliver K. Kelley, (*B.S., Chicago Technical College, 1925 and Massachusetts Institute of Technology*) now technical assistant to the vice president and general manager, Defense Systems Division, inventor in patents 2,910,832 for hydrodynamic torque converters; 2,911,786 for a reactor blade pitch of a hydrodynamic torque converter; and 2,917,137 for a fluid cooling system for liquid cooled friction brakes.

• **William H. Kolbe**, (*B.S.M.E., University of Michigan, 1950*) senior project engineer, inventor in patent 2,911,203 for a fuel injection enrichment device.

• **Gilbert K. Hause***, **Oliver K. Kelley***, and **Frank A. Swindell**, (*University of Florida and General Motors Institute*) assistant engineer in charge, Transmission Development Group, inventors in patent 2,911,785 for a reactor blade pitch control of a hydrodynamic torque converter.



• **William H. Kolbe***, and John Dolza, no longer with GM, inventors in patents 2,913,991 and 2,914,051 for a pump and a signal modifier for fuel injection system, respectively.

• **Charles A. Chayne**, (*B.S.M.E., Massachusetts Institute of Technology and Harvard University, 1919*) vice president in charge, and John Dolza*, inventors in patent 2,916,027 for a charge forming means.

• **Stanley H. Mick**, (*B.M.E., General Motors Institute, 1955*) project engineer, inventor in patent 2,918,047 for a split engine.

Fisher Body Division
Warren, Michigan

• **Joseph J. Kaller**, (*University of Detroit*) senior designer, inventor in patent 2,909,211 for a cover assembly for vehicle seat adjusting mechanism.

• **Clarence P. McClelland**, (*University of Detroit*) senior project engineer, and Armas G. Makela, no longer with GM, inventors in patent 2,910,716 for a windshield cleaner.

• **Charles J. Griswold, Jr.**, (*B.S. in engineering mechanics, Purdue University, 1953*) assistant engineer in charge of body engineering, inventor in patent 2,912,288 for a guide roller.

• **William E. Sehn**, (*B.M.E., General Motors Institute, 1951*) engineer in charge, Product Evaluation Department, inventor in patent 2,912,727 for a weather sealing member.

• **James D. Leslie**, (*B.M.E., University of Detroit, 1939*) engineer in charge, Mechanical Department, and **Gerhard Rehkugler**, designer, inventors in patent 2,913,066 for a door safety lock.

• **Ralph M. Stallard**, (*B.S.E.E., Michigan College of Mining and Technology, 1949*) senior production engineer, and Ming C. Hsu, no longer with Fisher Body, inventors in patent 2,914,109 for a method for making embossed decorative articles.

• **John W. Bloom**, senior project engineer, and **Basil Brubaker**, senior project engineer, inventors in patent 2,917,107 for a folding arm rest.

Frigidaire Division
Dayton, Ohio

• **Leonard J. Mann**, (*M.E., University of Cincinnati, 1940*) senior project engineer, inventor in patents 2,907,180 for refriger-

ating apparatus having air control means for multiple compartments and 2,912,834 for refrigerating apparatus.

• **James W. Jacobs**, (*B.S.M.E., University of Dayton, 1954*) manager, research and future products engineering, inventor in patents 2,907,426 and 2,919,340 for a coupling for transmitting torque and a domestic appliance, respectively.

• **Verlos G. Sharpe**, (*B.S.M.E., Purdue University, 1948*) section engineer, inventor in patent 2,908,148 for an ice block ejector.

• **Joseph B. Dunn**, (*B.S.M.E., Tri-State College, 1935*) factory contact, inventor in patent 2,909,314 for refrigerating apparatus.

• **Orson V. Saunders**, supervisor, major products, Refrigerated Appliance Engineering Department, inventor in patent 2,909,910 for refrigerating apparatus.

• **Margaret J. Andrew**, (*B.S., The Ohio State University, 1932*) experimental engineer, inventor in patent 2,910,207 for a dish rack for domestic appliance.

• **Robert D. Bremer**, (*B.S.E.E., Purdue University, 1934*) senior project engineer, and **John R. Simon**, senior tool engineer, inventors in patent 2,910,570 for a domestic appliance.

• **Robert Galin**, (*B.S.M.E., Robert College, Istanbul, Turkey, 1947, and M.S.M.E., University of Michigan, 1949*) senior project engineer and **Allen L. Everitt**, (*M.S. M.E., Purdue University, 1931*) section engineer, Inland Manufacturing Division, inventors in patent 2,911,170 for refrigerating apparatus.

• **Richard E. Gould**, (*B.S.M.E., 1923, and M.S.M.E., 1927, University of Illinois*) chief engineer, inventor in patent 2,911,798 for vehicle refrigerating apparatus.

• **John Weibel, Jr.**, (*B.S.M.E., Louisiana State University, 1948, and M.S.M.E., Purdue University, 1950*) senior project engineer, inventor in patent 2,913,166 for refrigerating apparatus.

• **John H. Heidorn**, (*General Motors Institute, 1947*) project engineer, inventor in in patent 2,913,168 for refrigerating apparatus.

• **Bobbie D. Moore**, (*University of Dayton*) special tester, and Philip L. Johnson, not with GM, inventors in patent 2,917,907 for an ice block harvester.

GMC Truck and Coach Division
Pontiac, Michigan

• **Edwin T. Todd**, (*B.A.M.E., and B.A. Aero.E., Stanford University, 1924; University of California; College of the Pacific, and Davis Agricultural College*) amphibious truck engineer, inventor in patent 2,908,241 for an amphibious vehicle.

• **Hans O. Schjolin**, (*B.S. degree, Karlstad College, Sweden, 1920, and Polytechnical Institute, Mittweida, Germany, 1923*) advance design engineer, inventor in patents 2,914,358 for a vehicle door and brake interlock system, and 2,918,805 for refrigerating apparatus.

• **Irwin K. Weiss**, now with Chevrolet Motor Division, inventor in patent 2,907,577 for an air suspension assembly for tandem axle vehicle.

Guide Lamp Division
Anderson, Indiana

• **John H. Diedring**, (*Fenn College*) engineering head, original equipment lamps, inventor in patents 2,909,653 and 2,918,570 for a spring located outlook lens and a snap in lens, respectively.

• **George W. Onksen**, (*B.I.E., General Motors Institute, 1956, and Purdue University*), staff engineer—Reliability; **Howard C. Mead**, (*Western Reserve University*) director of reliability; and Robert N. Falge, retired, inventors in patent 2,909,724 for testing and calibrating apparatus.

• **William T. Mears**, experimental engineer, inventor in patent 2,911,522 for a headlamp adjuster.

• **Gerald R. Broshar**, project engineer; **Ray Manning**, foreman, Inspection Department; and Robert N. Falge, retired, inventors in patent 2,911,523 for a headlamp adjuster.

• **Howard C. Mead***, and **Lloyd T. Fuqua**, (*DePauw University and American School of Chicago*) senior designer—drafting, inventors in patent 2,913,958 for a non-glare mirror.

Harrison Radiator Division
Lockport, New York

• **John W. Godfrey**, (*B.S.Chem., Canisius College, 1935*) assistant chief engineer; **John R. Hayden**, senior designer; and **Kenneth V. Nieman**, senior product designer, inventors in patent 2,914,012 for a marine heat exchanger.

• **Charles F. Whitmore**, senior project engineer, inventor in patent 2,916,892 for air conditioning system controls.

Hyatt Bearings Division
Harrison, New Jersey

• **Robert H. Koch**, (*Rutgers University*) assistant superintendent, primary operations, inventor in patent 2,913,859 for a method of making bearings.

Inland Manufacturing Division
Dayton, Ohio

• **Arthur J. Frei**, senior project engineer, inventor in patents 2,907,179 and 2,908,146 for ice making apparatus and a freezing device power unit, respectively.

• **Edward P. Harris**, (*M.E., Cornell University, 1931*) project engineer, inventor in patent 2,910,915 for a safety rear vision mirror.

• **Stanley R. Prance**, (*Wayne State University, 1926*) chief metallurgist, inventor in patent 2,911,323 for an electrostatic method and apparatus using non-conductive discharge means.

• **Max P. Baker**, (*A.B., Miami University, 1922*) project engineer, inventor in patents 2,917,334 and 2,919,150 for a ball joint and ball joint assemblies, respectively.

New Departure Division
Bristol, Connecticut

• **Clarence J. Ennis**, toolmaker, inventor in patent 2,908,115 for a honing mechanism.

Oldsmobile Division
Lansing, Michigan

• **George T. Jones**, (*University of Pittsburgh, 1937*) body engineer—Body Group, in-

ventor in patent 2,912,072 for a brake equalizing system.

• **Elliott M. Estes**, now chief engineer, Pontiac Motor Division, and **Donald C. Perkins**, body engineer, inventors in patent 2,916,325 for a seating arrangement for vehicle bodies.

• **Harold G. Axtman**, (*International Correspondence School and Purdue University Extension*) senior designer, inventor in patent 2,917,319 for a plural compartment fluid suspension for vehicles.

• **Kenneth E. Faiver**, (*B.S.E.E., Notre Dame University, 1924 and Ph.D., Rensselaer Polytechnic Institute, 1927*) senior project engineer, inventor in patent 2,918,305 for an air suspension system with pitch control.

GM Overseas Operations Division
New York, New York

• **Kenneth E. Buckman**, assistant chief engineer, No. 2 Plant, AC-Delco Division, Southampton, England, inventor in patent 2,908,350 for filter elements.

Packard Electric Division
Warren, Ohio

• **Robert E. Kirk**, (*Case Institute of Technology*) product designer, inventor in patent 2,911,610 for a terminal connector for circuit boards.

• **Robert C. Woofter**, (*Fenn College*) chief, Wiring Assemblies Design and Development Section, inventor in patent 2,919,-315 for an electric switch.

Pontiac Motor Division
Pontiac, Michigan

• **Clayton B. Leach**, (*A.B. in mathematics and chemistry, Park College, 1934, and General Motors Institute*) chassis engineer, inventor in patent 2,907,411 for a timing chain and fuel pump drive lubricating means.

• **John Z. DeLorean**, (*B.S.I.E., Lawrence Institute of Technology, 1948; M.S.A.E., Chrysler Institute, 1952; M.B.A., University of Michigan 1957; and Detroit College of Law*) assistant chief engineer in charge of advanced design and body, inventor in patent 2,912,085 for a brake mechanism.

• **Malcolm R. McKellar**, (*diploma in Automotive Engineering, General Motors Institute, 1941*) assistant motor engineer, inventor in patent 2,914,038 for a bearing cap to frame to oil pan seal.

GM Manufacturing Development Staff
Warren, Michigan

• **Ronald A. Featherstone**, (*B.S.M.E., Birmingham Institute of Technology, England, 1945*) staff engineer, and **William E. Rise**, (*Wayne State University and Detroit College of Applied Science*) senior process engineer, inventors in patent 2,908,066 for an assembly machine.

• **Robert B. Allured**, senior project engineer, and **John L. Walker**, (*B.S.M.E., University of Michigan, 1949*) design engineer, inventors in patent 2,912,105 for hardness testing and sorting.

• **Robert E. Colten**, (*B.S., University of Michigan, 1939*) staff engineer; and **Glenn E. Wanttaja**, (*B.S.E.E., Michigan College of Mining and Technology, 1950 and M.S. E.E., Wayne State University, 1956*) now with AC Spark Plug Division; and Frederick E. Booth, no longer with GM, inventors in patent 2,915,896 for a torsiograph.

• **William A. Fletcher**, (*General Motors Institute, 1930*) staff engineer in charge of advanced engineering, inventor in patent 2,917,823 for a method of cold forming tubular bodies having internal undercut grooves.

GM Research Laboratories
Warren, Michigan

• **James C. Holzwarth**, (*B.S.M.E., 1945, and M.S.M.E., 1948, Purdue University*) supervisor, Metallurgical Engineering Department and **Robert F. Thomson**, (*B.S.M.E., 1937; M.S.M.E., 1940; and PH.D., 1941, University of Michigan*) head, Metallurgical Engineering Department, inventors in patent 2,907,653 and 2,908,-567, both for a copper base alloy; 2,909,429 for a highly wear resistant zinc base alloy; 2,912,324 for a high wear resistant zinc base alloy and method of making same; and 2,908,564 for a ferrous base alloy.

These patent listings are informative only and are not intended to define the coverage which is determined by the claims of each one.

• **Alexander Somerville**, (*B.S.E.E., 1943; M.S.E.E., 1947; and Ph.D., 1950, Northwestern University*) supervisor, Isotope Laboratory, inventor in patent 2,909,204 for a composite bonded structure and method of making same.

• **Darl F. Caris**, (*B.S.E.E., 1926, and professional degree of E.E., 1932, University of Michigan*) now engineer in charge, Power Development Group, GM Engineering Staff, inventor in patent 2,910,974 for a speed control responsive device.

• **Eugene A. Hanysz**, (*B.S.E.E., 1945, and M.S.E.E., 1948, University of Michigan*) supervisor of electro-physical research sections, Physics Department, inventor in patent 2,912,853 for an ultrasonic transmission testing device.

• **Norman W. Schubring**, (*B.S.E.E., 1952 and M.S.E.E., 1959, Wayne State University*) senior research engineer, inventor in patent 2,912,854 for an ultrasonic surface testing device.

• **Robert T. Bockemuehl**, (*B.S.E.E., University of Michigan, 1952*) senior research engineer, inventor in patent 2,913,638 for an electronic relay.

• **Arthur F. Underwood**, (*M.S.M.E., and B.S.M.E., 1926, Massachusetts Institute of Technology*) manager, Research Laboratories, inventor in patent 2,914,367 for a sleeve bearing.

• **Charles W. Phelps**, (*General Motors Institute, 1936*) assistant head, Special Problems Department, inventor in patent 2,915,901 for a centrifugal fluid loading device.

• **Lawrence V. Puls**, (*B.S.Chem.E., Michigan College of Mining and Technology, 1953*) research engineer, and **William R. Vincent**, (*B.S. in chemistry, Eastern Michigan College, 1941*) research chemist, inventors in patent 2,916,401 for a chemical reduction nickel plating bath.

• **Eugene A. Hanysz***, and **Roger L. Saur**, senior physicists, inventors in patent 2,916,694 for a coating thickness gage.

• **Robert F. Thomson***, inventor in patent 2,917,818 for aluminum coated steel having chromium in diffusion layer.

Rochester Products Division
Rochester, New York

• **Howard H. Dietrich**, (*B.S.E.E., Purdue University, 1926 and Yale University*) patents, new devices, and project analysis engineer and Lucius W. Paterson, deceased, inventors in patent 2,908,363 for a carburetor.

• **John B. Burnell**, (*Massachusetts Institute of Technology and General Motors Institute, 1941*) assistant chief engineer and **Russell R. Roberts**, group leader, design or drafting, inventors in patent 2,915,914 for an idle speed control device.

• **Donald D. Stoltman**, (*B.S.M.E., Rensselaer Polytechnic Institute, 1947, and M.S. in Automotive Engineering, Cornell University, 1948*) senior project engineer, inventor in patent 2,916,269 for a combined injection and pressure carburetor fuel system.

• **Lawrence C. Dermond**, (*Purdue University and Tri-State College*) staff engineer, inventor in patent 2,916,270 for idle fuel control.

• **Elmer Olson**, (*Lewis Institute*) engineering consultant, inventor in patent, 2,916,-271 for a carburetor vent arrangement.

• **Homer V. Krautwurst**, (*B.S.M.E., University of Rochester, 1941*) senior project engineer, inventor in patent 2,916,596 for a cigar lighter and mounting therefor.

Saginaw Steering Gear Division
Saginaw, Michigan

• **Charles W. Spalding**, (*B.S.M.E., Michigan State University, 1940*) design engineer, and Walter H. West, no longer with GM, inventors in patents 2,908,137 and 2,916,882 for a hydraulic power brake unit and a hydraulic power brake booster, respectively.

• **Earl W. Glover**, designer, and **Owen R. Rittenhouse**, (*B.S.M.E., Carnegie Institute of Technology, 1941*) senior project engineer, inventors in patent 2,916,945 for a steering gear.

• **Joseph H. Verbrugge**, (*General Motors Institute, 1941*) now development engineer at Buick Motor Division and **Donald E. Deford**, (*B.S.I.E., General Motors Institute, 1952*) design engineer, inventors in patent 2,917,079 for a fluid power steering control valve.

• **Arthur F. Bohnhoff**, (*B.S.M.E., Michigan College of Mining and Technology, 1938*) senior project engineer, and **Kenneth E. Faiver**, (*B.S.E.E., Notre Dame University, 1924 and Ph.D., Rensselaer Polytechnic Institute, 1927*) senior project engineer, inventors in patent 2,917,320 for a vehicle suspension.

GM Styling Staff
Warren, Michigan

• **Stefan Habsburg Lothringen**, (*B.S. M.E., Massachusetts Institute of Technology, 1955*) assistant chief engineer, Research Studio, and **Clark E. Quinn**, research engineer, GM Research Laboratories, Oldsmobile Division, inventors in patent 2,917,320 for a vehicle suspension.

• **Robert F. Smith**, (*General Motors Institute*) assistant engineer in charge, Product and Exhibit Design Studio, inventor in patent 2,913,571 for a luminous ceiling.

• **Joseph H. Gilson**, (*Brooklyn Polytechnic Institute*) general supervisor, Advanced Engineering Development, inventor in patent 2,916,327 for a power operated convertible top header latch.

• **Joseph D. Bulone**, (*Cleveland School of Art*) designing sculptor, inventor in patent 2,916,895 for an ice block releasing and storing unit.

• **Richard H. Champion**, senior layout man, and **Joseph H. Gilson***, inventors in patent 2,917,124 for a vehicle body exhaust port closure.

• **Herman J. Thomas**, (*Wayne State University and Lawrence Institute of Technology*) group leader of exterior ornamentation group, Exterior Engineering and Drafting Department, inventor in patent 2,918,317 for a door latch for pillarless automobile.

Ternstedt Division
Detroit, Michigan

• **John P. Bogater**, (*B.S.M.E., Detroit Institute of Technology, 1937*) design group leader; **Samuel F. Loria**, (*B.S.M.E., Detroit Institute of Technology, 1939*) chief draftsman; and Nelson E. Putnam, deceased, inventors in patent 2,908,415 for a lift gate support for station wagon.

• **LaVerne B. Ragsdale**, (*University of Detroit; Franklin College; and B.S.M.E., Lawrence Institute of Technology, 1939*) divisional sales manager, inventor in patent 2,908,934 and 2,917,350 for a hinge counterbalance and hold-open and a seat adjusting mechanism, respectively.

• **Albert J. Colautti**, (*B.M.E., Detroit Institute of Technology, 1952*) design group leader, inventor in patent 2,909,624 for a circuit controller.

• **Russel G. Corbin**, (*B.S.M.E., University of Michigan, 1950*) design group leader, inventor in patent 2,911,247 for a vehicle tail gate latch.

• **Alfonsas Arlauskas**, (*B.S.M.E., Bradford Technical College, England, 1953*) design group leader, inventor in patents 2,914,314 and 2,918,275 for a window regulator mechanism and operating apparatus for a pivoted window, respectively.

• **Paul Widmer**, (*Machine Design Diploma, Niedernzwil, Switzerland, 1936*) senior designer, inventor in patent 2,916,176 for a telescopic stay for automotive vehicle lift gate and the like.

• **Barthold F. Meyer**, (*B.S.M.E., Pratt Institute, 1939, and Johns Hopkins University*) engineering group supervisor, Product Engineering Department and **Nicholas Toruk**, (*B.S.M.E., University of Detroit, 1951*) senior project engineer, inventors in patent 2,916,566 for a circuit controller.

• **Frank A. Croskey**, research engineer, and **Charles D. Tuttle**, (*Ph.D., Michigan State University, 1933*) senior experimental physicist, inventors in patent 2,916,576 for a fluid flow switch actuating mechanism.

• **Alfonsas Arlauskas***, and Arthur W. Hollar, Jr., no longer with GM, inventors in patent 2,918,274 for a window regulator mechanism.

Technical Presentations by GM Engineers and Scientists

The technical presentation is another way in which information about current engineering and scientific developments in General Motors can be made available to the public. A listing of speaking appearances by General Motors engineers and scientists, such as that given below, usually includes the presentation of papers before professional societies, lecturing to college engineering classes or student societies, and speaking to civic or governmental organizations. Educators who wish assistance in obtaining the services of GM engineers and scientists to speak to student groups may write to the Educational Relations Section, Public Relations Staff, General Motors Corporation, General Motors Technical Center, Warren, Michigan.

The following GM personnel made recent technical presentations.

Automotive Engineering

Maurice Platt, chief engineer, Vauxhall Motors Limited, before the Automobile Division, Institution of Mechanical Engineers, Coventry, Oxford, and Luton, England, title: The Structure of the Automobile.

William A. Turunen, head, Engineering Development Department, GM Research Laboratories, before the student chapters of the Society of Automotive Engineers and the American Society of Mechanical Engineers, Michigan College of Mining and Technology, Houghton, title: Vehicular Gas Turbine Engines.

Donald P. Marquis, assistant chief engineer, Saginaw Steering Gear Division, before the student chapter of the S.A.E., General Motors Institute, Flint, title: Future High Angle Universal Joints.

Max Roensch, assistant chief engineer, Experimental Tests, Chevrolet Motor Division, before European engineers and professors, Paris, France, title: Chevrolet's New Engineering Laboratory.

John B. Burnell, assistant chief engineer, Research and Development, Rochester Products Division, before the Men's Club of the Rochester Central YMCA, Rochester, New York, discussion of basic carburetor engineering and showing of the film "Joe Period and the Carburetor."

From the GM Engineering Staff: **William H. Kolbe**, section engineer, before the Exhaust System Task Group, Automobile Manufacturers Association, Detroit, title: A Status Report on the GM Catalytic Converter; **Craig Marks**, assistant engineer in charge, Power Development Group, before the Consolidated Electrodynamics Corporation Engineering Forum, Pasadena, California, title: The Potential of Unconventional Powerplants for Vehicle Propulsion; **Thomas H. Mitzelfeld**, section engineer, before the student chapter of the S.A.E., Lawrence Institute of Technology, Detroit, title: The Firebird III Aluminum Engine Driven Accessory Package; and **Edwin E. Nelson**, project engineer, before engineering students of The Ohio State University, Columbus, title: A New Look at High Compression Engines.

Gordon H. Hale, project engineer, AC Spark Plug Division, before the 1100th Maintenance and Supply Group, United States Air Force, Bolling Air Force Base, Washington, D. C., title: Aircraft Spark Plugs.

Before the national meeting of the Highway Research Board, Washington, D. C.: **Kenneth A. Stonex**, assistant director, GM Proving Grounds, titles: Review of Vehicle Dimensions and Performance Characteristics, and Roadside Design for Safety; **Robert Herman**, head, Theoretical Physics Department, GM Research Laboratories, title: Theory of Traffic Flow; and **Joseph B. Bidwell**, head, Engineering Mechanics Department, **Albert F. Welch**, head, Electronics-Instrumentation Department, and **E. A. Hanysz**, supervisor, Physics Department, GM Research Laboratories, title: Electronic Highways.

Before the Symposium on the Theory of Traffic Flow, GM Technical Center: **Joseph B. Bidwell**, GM Research Laboratories, title: The Car-Road Complex, and **Robert Herman**, GM Research Laboratories, and **R. B. Potts**, University of Adelaide, South Africa, title: Single Lane Traffic Theory and Experiment.

From the GM Proving Grounds: **Kenneth A. Stonex**, assistant director, before the Detroit Street and Traffic Control Committee, title: Roadside Design for Safety; and **T. M. Fisher**, administrative engineer, before the Genesee County Traffic Safety Commission Board of Directors, Flint, title: Roadside Hazards.

Before various S.A.E. section meetings: **Richard C. Balmer**, engine designer, GMC Truck and Coach Division, before the Richmond, Virginia, section, title: Development of the GMC Engine Family; **Elmer F. DeTiere**, supervisor, carburetor test and calibration, Rochester Products Division, before the Syracuse, New York, section, title: Fuel Injection; **H. D. Wright**, project engineer, AC Spark Plug Division, before the Detroit section, title: Electroluminescence Applied to Instrument Clusters; **Zora Arkus-Duntov**, staff engineer and director of high performance vehicle design, Chevrolet Motor Division, before mid-Michigan section, title: Stability—Performance; **Nelson E. Farley**, staff engineer and director of Chevrolet Motor Division's proving ground facilities, before the Detroit section, senior member of panel discussing the subject Cross Country Testing; and **Robert E. Harvie**, chief metallurgical engineer, Chevrolet Motor Division, before the Wichita, Kansas, section and the mid-continent section, Ponca City, Oklahoma, title: Development of Transaxle Fluid for the Chevrolet Corvair.

Engineers from Chevrolet Motor Division who made the presentation, The Chevrolet Corvair, included: **Kai H. Hansen**, staff engineer, before the southern California S.A.E. seminar, Los Angeles; **William G. Wallace**, area product engineer, before the Dayton, Ohio, section of the S.A.E.; **William B. Yacus**, project engineer, before the Framingham, Massachusetts, Engineers Club; **Max M. Roensch**, assistant chief engineer, Experimental Tests, before the Pittsburgh section of the S.A.E.; and **Phillip J. Passon**, resident engineer, St. Louis assembly plant, before the central Illinois section of the S.A.E.

S.A.E. Annual Meeting

The following GM personnel made presentations at the S.A.E. 1960 annual meeting, Detroit, January 11-15.

From AC Spark Plug Division: **H. C. Zeisloft**, engine controls, title: Terrestrial Tilling in the Space Age, and **R. O. Helgeby**, staff engineer, title: Speedometer Standardization.

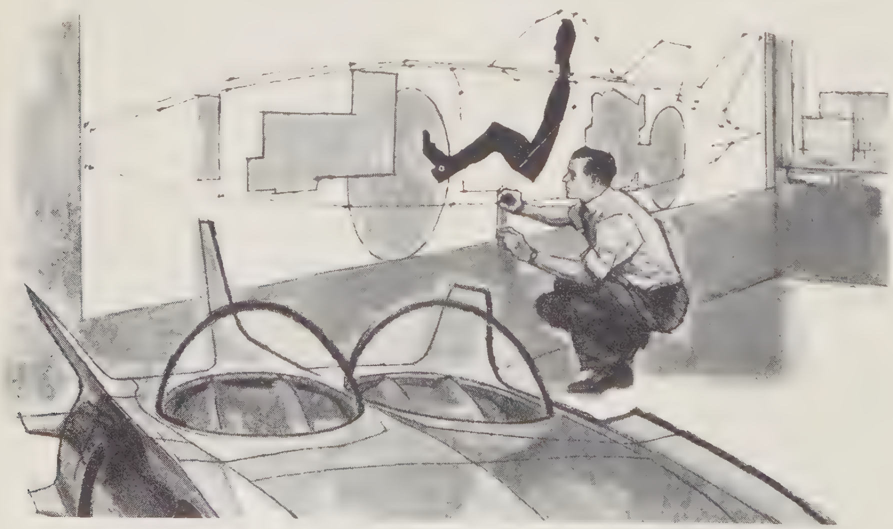
From Buick Motor Division: **Forest R. McFarland**, executive assistant chief engineer, chairman of the session The Big Three Smaller Cars.

From Cadillac Motor Car Division: **Robert J. Templin**, staff engineer, panel member discussing the subject Reduction of Air Pollution by Control of Emission from Automotive Crankcases.

From Chevrolet Motor Division: **Robert E. Harvie**, chief metallurgical engineer, **Edward L. Nash**, senior project engineer, and **John W. Clark**, senior project engineer, title: Development of Transaxle Fluid for the Chevrolet Corvair; and **Kai H. Hansen**, staff engineer, **Frank J. Winchell**, assistant chief engineer, Research and Development, and **Robert P. Benzinger**, design engineer, title: The Chevrolet Corvair.

From the GM Engineering Staff: **James J. Gumbleton**, project engineer, title: Radioactive Cylinders—A Tool for Wear Research.

From the GM Research Laboratories: **Frank Quackenboss**, research associate, and **A. V. Butterworth**, research associate, title: Constructs, Models, and Systems; **Norman A. Hunstad**, assistant head, Fuels and Lubricants Department, **Robert A. Wilkins**, project mechanic, **Robert E. Osborne**, research engineer, and **Ellard D. Davison**, research engineer, title: Developing Transaxle Fluid; **Gregory Flynn**, head, Mechanical Development Department, **F. Earl Heffner**, senior research engineer, and **Worth H. Percival**, assistant head, Mechanical Development Department, title: GMR Stirling Engine—Part of the Stirling Engine Story—1960 Chapter; **F. E. Jamerson**, senior nuclear physicist, title: Thermionic Direct Conversion Studies With a Noble Gas Plasma Diode; **Eugene B. Jackson**, librarian, title: A Guide to Automotive Engineering Literature: **Joseph T. Olsztyn**, senior mathematics programmer, **Barrett Hargreaves**, research engineer, **Theodore J. Theodoroff**, research physicist, and **Edwin L. Jacks**, supervisor, Special Problems Department, title: The DYANA Computing System and its Applications; **Robert L. Dega**, supervisor, Mechanical Development Department, and **James D. Symons**, research engineer, title: Seal Testing to Establish Quality Control Specifications Can Reduce "Leakers"; **Gene L. Leithauser**, assistant head, Polymers Department, title: Influence of Variations in the Surface Properties of Steel on the Corrosion Resistance of Body Panels; **Paul A. Bennett**, supervisor, Fuels and Lubricants Department, **Marvin W. Jackson**, research engineer, **Chester K. Murphy**, research engineer, and **Richard A. Randall**, senior research engineer, title: Reduction of Air Pollution by Control of Emission from Automotive Crankcases; and **C. F. Nixon**, head, Electrochemistry Department, title: How the S.A.E. Cooperative Engineering Program Brings Benefits to Industry.



Computers

Robert K. Louden, project engineer, Buick Motor Division, before the Flint, Michigan, Optimist Club and also the National Association of Machine Accountants, Flint, title: Engineering Usage of Digital Computers.

Robert H. Kohr, supervisor, Engineering Mechanics Department, GM Research Laboratories, before the Eastern Joint Computer Conference, Boston, regional meeting, title: Real-Time Automobile Ride Simulation.

Donald E. Hart, assistant head, Special Problems Department, GM Research Laboratories, before joint meeting of The Institute of Management Sciences and American Institute of Industrial Engineers, Detroit chapters, title: Digital Computers.

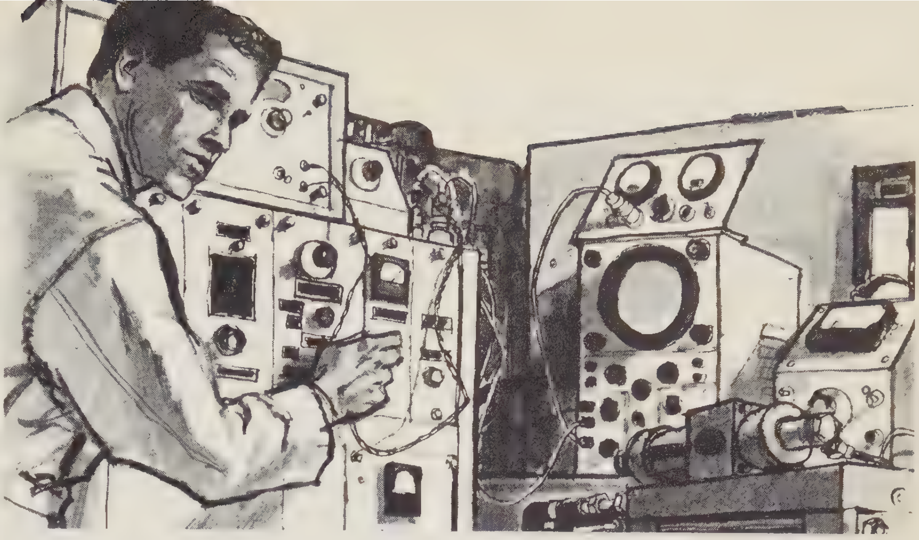
Electrical Engineering

B. H. Hefner, electrical engineer, Electro-Motive Division, before the A.S.M.E., Atlantic City, New Jersey, title: Economics of Decentralized Peaking Power For the Utilities.

E. G. Lommel, plant engineer, Detroit Transmission Division, before Plant Engineering Conference, General Electric Company, Nela Park, Cleveland, Ohio, title: High Bay Lighting at Detroit Transmission Division.

From Delco Radio Division: **F. L. Hughes**, supervisor, Field Service, before graduate training class in transistors, Purdue University, title: Analyzing Transistor Circuits; **W. C. Sahm**, field service engineer, before the Television Electronics Service Association of New Orleans, Louisiana, title: New 1960 Elec-

tronic Products; **R. H. Wright,** field service engineer, before engineers of the Packard Electric Division, title: Transistor Fundamentals; **R. E. Beard,** field service engineer, before the Omaha, Nebraska, chapter of the Institute of Radio Engineers, title: Transistors; and **W. C. Caldwell,** field service engineer, before the engineer-in-plant training group, Allison Division, title: Transistor Fundamentals and Troubleshooting Transistor Circuits.



Guided Missiles and Space Technology

From AC Spark Plug Division's Milwaukee, Wisconsin, plant: **James H. Bell,** director, guidance and navigation, before Delta Chi Sigma, University of Wisconsin, title: Inertial Guidance; **A. R. Colgan,** technical coordinator, before Holy Ghost Men's Club Lutheran Association, Milwaukee, title: AC Spark Plug's Role in The Guided Missile Program; **A. J. Italiano,** head, project office, THOR engineering, before Brookfield, Wisconsin, High School Math and Radio Clubs, title: Missiles From Here to There; **Harry Goble,** senior draftsman, before students of Oak Creek, Wisconsin, Junior High School, title: Space and Man and His Progress; **Robert James,** senior project engineer, before Men's Club, Ebenezer Lutheran Church, Milwaukee, title: Missile Guidance Systems; **Paul Parry,** research associate, before American Institute of Electrical Engineers and the Institute of Radio Engineers, Northwestern Technological Institute, Evanston, Illinois, title: Inertial Guidance; **Joseph Malone,** THOR engineering contracts administrator, before Greater Milwaukee Council of Churches, title: What the Missile Means to Them and Why the Missile; **Paul Blasingame,** director of engineering, before Society for Advancement of Management, Milwaukee, title: Space Travel—Sense or Nonsense; **Ray A. Berg,** head, general systems engineering, before Lincoln Elementary School, Menomonee Falls, Wisconsin, title: Missile Talk; and **Jack Schmidt,** project leader, before Trinity Evangelical and Reformed Church, Milwaukee, title: Missiles, Milwaukee, and You.

From Allison Division: **A. J. Sobey,** preliminary design engineer, before Foremen's Club, Kokomo, Indiana, title: Why Explore Space; and **Herbert L. Karsch,** project manager, advanced weapon systems, before the Science Seminar, Indianapolis Technical High School, title: Missiles and their History.

Before the American Rocket Society, Washington, D. C.: **C. L. Walker,** supervisor, heat transfer and fluid dynamics, Research Engineering Department, Allison Division, title: A Heat Storage System for Satellite Power Plants, and **T. R. Swartwout,** auxiliary power devices, Allison Division, title: Advanced Reciprocating Engine Power Plants for Auxiliary Power in Satellite and Space Vehicles.

Before the DCF Material Reserve Officers, Pentagon Building, Washington, D. C.: **T. F. Nagey,** director of research, Aircraft Engineering, Allison Division, title: Research Programs at Allison, and **J. E. Knott,** assistant director of engineering, Allison Division, title: Allison's Role in Space.

A. H. Kelso, manager, Instrument Bearing Development and Contract, New Departure Division, before Kiwanis Club, Sandusky, Ohio, title: Bearings for Rockets and Missiles.

Manufacturing

LeRoy Eckert, reliability engineer, Allison Division, before joint meeting of the American Society of Quality Control and the American Institute of Industrial Engineers, Indianapolis, Indiana, title: Design Reliability Prediction for Low Failure Rate Mechanical Parts.

John F. Cantalin, engineer-in-charge, Production Engineering Activity, Fisher Body Division, before Worcester, Massachusetts, section, American Welding Society, title: Resistance Welding Applications in Auto Body Production.

W. E. Lovell, engineer-in-charge, Process Engineering, Detroit plant, Ternstedt Division, before Grand Rapids, Michigan, section of the American Electroplaters' Society, title: Dual Chrome Plating.

Harry E. Welker, senior process engineer, Guide Lamp Division, before Cincinnati, Ohio, section, American Electroplaters' Society, title: How To Train Foremen and Operators in the Most Efficient Application of Buffs and Compounds.

From the GM Manufacturing Development Staff: **Frank H. Williams,** staff engineer, before the student chapter, S.A.E., University of Michigan, title: Process Development in Tool Engineering; **I. E. Poston,** senior engineer, before the American Society of Tool Engineers, Kokomo, Indiana, title: Recent Developments in Plastics Tooling; and **D. J. Agresta,** senior engineer, before the National Screw Machine Products Association, Detroit, title: Application of Chemistry in Industry.

From Delco Products Division: **Leo J. Nartker,** superintendent, Quality Control Department, before the Engineering Institutes Group, University of Wisconsin Extension Division, Madison, title: A Method of Selecting Sampling Plans on a Basis of Minimum Costs; and **Milton E. Feldstein,** manager, Inspection and Standards, and **Robert Beaman,** supervisor, Work Standards, before the Industrial Methods Society, Dayton, Ohio, title: Application of Pre-Determined Motion Times.

From AC Spark Plug Division's Milwaukee plant: **M. L. Stratton,** director of quality control, before the Third Engineering Institute on Inspection Organization, University of Wisconsin Extension Division and the College of

Engineering, title: Selection and Training of Inspectors; and **John Hepp** and **Don Fleming**, engineers, Reliability and Standards, before the Sixth National Symposium on Reliability and Quality Control, sponsored by the A.S.Q.C., A.R.E.E., and I.R.E., titles: Surveilance Testing of Purchased Parts and Improvement in Missile Guidance Application, respectively.

Metallurgy

D. J. Henry, assistant head, Metallurgical Engineering Department, GM Research Laboratories, before the American Society for Metals, Beaver Valley section, Rochester, Pennsylvania, title: Gas Turbine versus Piston Engine: Metallurgical Aspects.

Kenneth B. Valentine, metallurgical engineer, Pontiac Motor Division, delivered the American Society for Metals educational lecture, Detroit, title: Some Engineering Properties of Carbonnitrided Cases.

C. F. Nixon, head, Electrochemistry Department, before the national meeting of the American Zinc Institute, Detroit Symposium, title: American Zinc Institute Detroit Symposium on Plating of Zinc Base Die Casting—Remarks.

Carl F. Joseph, technical director, Central Foundry Division, before General Motors Institute foundry students, Flint, title: Engineering Aspects of ArmaSteel and CentraSteel.

Miscellaneous

Martin J. Caserio, general manager, Delco Radio Division, before Teachers and Clergymen of Howard County, Indiana, title: Sponges or Computers?

Elmer E. Braun, works manager, Central Foundry Division, before the Detroit chapter of the A.F.S., title: A Full House.

Before the 1959 A.A.A.S. Conference on Communicating Science, Chicago: **Eugene B. Jackson**, librarian, GM Research Laboratories, title: Reporting Scientific Research—An Industrial Point of View, and **Roy P. Trowbridge**, director, Engineering Standards, GM Engineering Staff, title: Accelerated Progress in the Automotive Decimalization Program.

From Allison Division: **W. S. Castle**, project head, Turbine Engineering, before the Indiana section of the S.A.E., Indianapolis, title: Model 250 Engine, and **G. J. Clingman**, commercial service, Aircraft Engines Operations, before the New Whiteland, Indiana, Optimist Club, title: The Lockheed Electra Story.

From AC Spark Plug Division: **Karl Schwartzwalder**, director of research, and **Robert W. Smith**, staff scientist, before students and engineering faculty of the University of British Columbia, Vancouver, titles: Ceramic Materials and AC Products, respectively; **William P. Shulhof**, senior engineer, before the Five Talent Group and Flint Science Teachers, title: Phase Equilibrium Systems; and **R. N. Johnson**, engineer, before the U. S. Marine Corps Reserve, Flint, title: Functioning of the Browning Automatic Rifle.

L. R. Buzan, assistant head, Administrative Engineering, GM Research Laboratories, before the Society of Technical Writers and Editors Seminar, Wayne State University, Detroit, title: Who's Prepared for Technical Writing?

Research

From the GM Research Laboratories: **Bernard J. Riley** and **S. E. Beacom**, senior research chemists, before the A.E.C. Conference on Industrial Uses of Radioisotopes, Detroit, title: Studies of Electrodeposition Phenomena Using Radiotracer Techniques; **Robert Herman**, head, Theoretical Physics Department, **D. C. Gazis**, senior research scientist, and **R. F. Wallis**, consultant, before the Second Conference on Semiconductor Surfaces, Naval Ordnance Laboratory, Silver Springs, Maryland, title: Surface Elastic Waves in Semiconductors; **R. C. Frank**, senior research physicist, and **J. E. Thomas**, Sylvania Electric Company, before the American Physical Society, national meeting, Cleveland, title: The Diffusion of Hydrogen in Germanium; **Manuel Ben**, supervisor, Electrochemistry Department, before the American Electroplaters' Society, section meeting, Montreal, Quebec, Canada, title: Functional Chromium Plating at the GM Research Laboratories; **C. R. Russell**, consulting engineer, Administrative Engineering Department, before the Society of Technical Safety Engineers, local meeting, Detroit, title: Radiation Safeguards; **C. F. Nixon**, head, Electrochemistry Department, before the American Electroplaters' Society, Chicago branch, title: Progress Report on the Search for Durable Plating; and **Kan-Chen Peng**, senior research mathematician, before the Industrial Mathematics Society, local meeting, Detroit, title: A "Chain Block" Experimental Design With an Application in Fuel Testing.

W. E. Hauth, staff scientist, AC Spark Plug Division, before Five Talent Group and Flint Science Teachers, title: Crystal Chemistry.

From Delco Radio Division: **F. E. Jaumot, Jr.**, director, Research and Development, Semiconductors, before graduate school students, U.C.L.A. Extension, title: Power Conversion Through Solid State Means; and **K. W. Doversberger**, supervisor, Evaluations and Applications Section, and **J. S. Schaffner**, manager, Evaluations and Applications Section, before senior project engineers, Ford Motor Company, Detroit, titles: Silicon Power Rectifiers and Reliable Design for Semiconductor Devices, respectively.

Technical Careers

Peter Wallack, chief engineer, Product Engineering, New Departure Division, before evening students, Technical Institute Program, Wilcox Tech, Meriden, Connecticut, title: Expanding Opportunities for Technicians in Modern Day Industrial Operations.

A. H. McVeigh, layout engineer, and **S. E. Wilson**, foreman, tool room, B-O-P Assembly Division, Kansas City plant, before engineering students of the University of Kansas, Lawrence, title: Opportunities for Engineers in Industry.

Solution to the Previous Problem:

Determine the Angular Setting of Spokes Used in the Second Turbine of an Automatic Transmission

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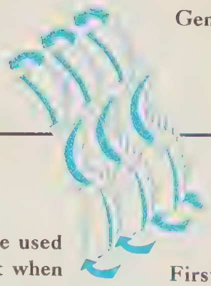


The streamline shaped spokes contained in the hub structure of the second turbine used in one type of automatic transmission transmit a driving torque to an output shaft when rotated through the flow path of the torque converter. To obtain the best overall performance of the converter and also to minimize drag loss, the spokes must be properly oriented relative to the converter blading. This is the solution to the problem presented in the January-February-March 1960 issue of the GENERAL MOTORS ENGINEERING JOURNAL. The correct angular orientation the spokes should have to provide minimum drag at the specified operating conditions is *61.7°*.

First step: apply principles of continuity of flow and moment of momentum

A SATISFACTORY method to use for solving the problem is to assume that the fluid concentrates at one radius point at each section around the flow path. The theoretical line formed by the radius points in the radial plane through the centerline of rotation is called the design path. The design path radii are frequently calculated as a root mean square of the corresponding radii at the boundaries of the passage formed by the shell and core surfaces at each design section, or

$$R = \left(\frac{R_1^2 + R_2^2}{2}\right)^{1/2} \qquad (1)$$

where

R = design path radius

R_1 = shell radius

R_2 = core radius.

The first step in the solution is to obtain the circulation flow rate, or volume rate of flow, Q from which necessary vector relationships can be established.

The torque equations to be presented are based on continuity of flow and moment of momentum principles.

Using the pump torque equation, the circulation flow rate Q at the specified conditions of operation can be calculated as follows:

$$T_p = \left(\frac{d}{g}\right) Q \left[(R_p)(S_p) - (R_s)(S_s) \right] \qquad (2)$$

where

T_p = pump torque (lb-ft)
d = density of the fluid (lb per cu ft)
g = gravitational constant (ft per sec²)
Q = basic circulation flow rate in a plane containing the longitudinal axis of the transmission (cu ft per sec)
R_p = pump discharge radius (ft)
S_p = tangential component of the fluid absolute velocity (fluid absolute whirl) at the discharge radius of the pump (ft per sec)
S_s = tangential component of the fluid absolute velocity (fluid absolute whirl) at the discharge radius of stator (ft per sec).

By substitution:

$$S_p = 2\pi\,(R_p)(N_p) + F_p\,(\tan a_p) \qquad (3)$$
$$S_s = 2\pi\,(R_s)(N_s) + F_s\,(\tan a_s) \qquad (4)$$

where

N_p = pump speed (rpm)
F_p = $Q \div A_p$ (ft per sec)
a_p = pump discharge angle (degrees)
N_s = stator speed (rpm)
F_s = $Q \div A_s$ (ft per sec)
a_s = stator discharge angle (degrees).

It should be noted that in the system of angle definition used, angle values never exceed 90° in magnitude and the tangent of the angle carries the same sign as the angle. This is a hydraulic system in which the components of tangential velocity (whirl) in the direction of pump rotation are positive and components of tangential velocity counter to pump rotation are negative.

The circulation flow rate Q can be expressed as:

$$Q = (F)(A) = Q_p = (F_p)(A_p) = Q_s = (F_s)(A_s) = Q_t = (F_t)(A_t)$$

where

F, with the appropriate subscript, represents the average flow velocity at the particular point in the torus and in a plane corresponding to Q (ft per sec)

A, with the appropriate subscript, represents the cross sectional area perpendicular to F at the corresponding location (sq ft).

The pump torque equation (2) can now be expressed as:

$$T_p = \left(\frac{d}{g}\right) Q \left\{\left[2\pi (R_p^2)(N_p) + \left(\frac{Q}{A_p}\right)(\tan a_p)(R_p)\right] - \left[2\pi (R_s^2)(N_s) + \left(\frac{Q}{A_s}\right)(\tan a_s)(R_s)\right]\right\} \quad (5)$$

Rearranging equation (5) in quadratic form allows a direct solution for the circulation rate Q.

$$Q^2\left[\frac{(\tan a_p)(R_p)}{A_p} - \frac{(\tan a_s)(R_s)}{A_s}\right] + Q\left[2\pi (R_p^2)(N_p) - (R_s^2)(N_s)\right] - \frac{T_p}{\frac{d}{g}} = 0. \quad (6)$$

Substituting known values into equation (6) gives:

$$+Q = 2.335 \text{ cu ft per sec.}$$

Since it is not possible to have a negative value for Q, the alternate solution to equation (6) is meaningless.

The next step is to define the conditions to be satisfied at the spokes. The condition of minimum drag requires the long axis of the streamline section to be aligned with the fluid as it approaches the leading edge of the spokes after leaving the turbine. This, in turn, means there will be no angular change in fluid velocity as the fluid flows through the spoke member. Therefore, a torque equation written for conditions from turbine discharge to the spoke trailing edge can be equated to zero.

$$0 = T_{t\text{-}sp} = \left(\frac{d}{g}\right) Q \left[2\pi (R_{sp}^2)(N_{sp}) + \left(\frac{Q}{A_{sp}}\right)(\tan a_{sp})(R_{sp}) - 2\pi (R_t^2)(N_t) + \left(\frac{Q}{A_t}\right)(\tan a_t)(R_t)\right] \quad (7)$$

Solving equation (7) for $\tan a_{sp}$ gives:

$$\tan a_{sp} = \frac{\left[\left(\frac{Q}{A_t}\right)(\tan a_t)(R_t) + 2\pi (R_t^2)(N_t) - 2\pi (R_{sp}^2)(N_{sp})\right]}{\left(\frac{Q}{A_{sp}}\right)(R_{sp})} \quad (8)$$

Substituting known values into equation (8) gives:

$$\tan a_{sp} = -1.86$$
$$a_{sp} = -61.73°.$$

The spokes should be oriented in the same sense as the turbine exit and at nearly 20° greater angle relative to the axis of rotation.

If desired, other conditions of operation may be examined to determine the compatibility of the solution at other conditions. The final design of such a mechanical component requires a thorough understanding of the full range of mechanical and hydraulic conditions, augmented by mechanical and hydraulic tests designed to pinpoint the optimum design arrangement. Construction of vector diagrams corresponding to the conditions described by the equations is helpful to visualize prevailing conditions at the various points considered.

Any geometrically consistent system of angle definition will yield the same results when properly applied.

Bibliography

Literature useful in the solution of this problem includes the following:

Society of Automotive Engineers Handbook, sections on Hydrodynamic Drive Terminology and Symbols for Hydrodynamic Drives.

Reprints and Educational Aids Available to Educators

Reprints of some previously published General Motors Engineering Journal papers are available free to educators on request. The available reprints include:

- How to Organize and Write Effective Technical Reports
- Characteristics and Organization of an Oral Technical Report
- Preparation and Evaluation of an Industrial Report
- Development of the Annual New Car Model—From Styling to Assembly
- The Application of Nomograms to the Solution of an Engineering Problem
- Typical Problems in Engineering. (Thirty-four problems in engineering are presented in booklet form. A separate booklet contains the solutions.)

Also available are reprints of a chart "Doorways to Science and Engineering Careers," which is intended as supplementary information for use by educators concerned with the counseling and guidance of students interested in science or engineering careers.

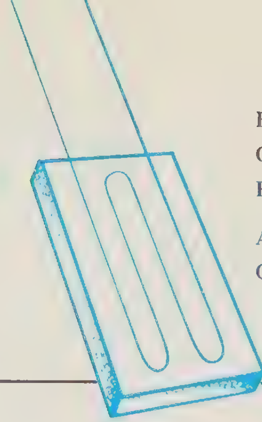
A teaching aid illustrating automotive design and drafting practice is available in the form of a Design Engineering and Drafting Problems Kit. This kit contains four typical automotive design and drafting problems: the design of a torque ball, the development of a front door window regulator assembly, the design of an instrument panel support, and the design of helical oil pump gears.

Educators desiring reprints of the papers or the other educational aids listed above may write to:

Educational Relations Section
Public Relations Staff
General Motors Corporation
General Motors Technical Center
Warren, Michigan.

A Typical Problem in Engineering:

Determine the Basic Design Parameters for a Strain Gage, Shaft-Type Torquemeter



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Instrumentation plays a very important role in the success of scientific and engineering investigations. Observed phenomena often are of little value in research and engineering work unless they can be measured and converted into some usable form. In most cases, man's inherent sensory systems are not capable of making the required measurements. Instrumentation, therefore, becomes a necessary tool of research and engineering to extend the human senses and provide quantitative information on both static and dynamic phenomena. Of particular importance to a researcher or engineer is the availability of an instrument which will accurately sense the phenomena to be measured. One sensing device, or transducer, frequently used is the resistance-wire strain gage. Strain gages are used in measurement systems because they are readily adaptable to the sensing of pressures, forces, and motions. A frequent use of the strain gage is in the measurement of torque. The problem presented here is to determine the necessary design parameters for a strain gage, shaft-type torquemeter. The parameters to be determined are: (a) shaft diameter of the gage section, (b) the proper type of strain gage to use and how it should be mounted on the shaft, and (c) the magnitude and polarity of the output signal.

Apply fundamentals of strength of materials and electrical engineering

THE CONSTANT challenge to meet measuring requirements in almost every field of research and engineering has brought about significant developments in instrumentation techniques in recent years. Not too long ago, time was measured by a stop watch and distance with a steel rule. Today, millionths of a second or of an inch are commonplace measurements. Also, scientists and engineers had to be satisfied at one time with instrumentation which could measure only static or slowly changing phenomena. Today, dynamic measuring systems are available to measure phenomena varying at the rate of millions of cycles per second.

Because of the nature of his work, the researcher often finds himself working in areas where no suitable "off the shelf" instrumentation exists to meet his measuring requirements. As a result, existing instruments often must be modified or new instruments designed and built.

The greatest difficulty encountered by a researcher in regard to instrumentation is how to sense the phenomena to be measured and obtain an output signal which will be indicative of the phenomena. An important component of a measurement system, therefore, is the sensing device, or transducer, which must be properly designed if the system is to operate satisfactorily.

The problem to be presented deals with establishing basic design parameters for a transducer which is to meet specific requirements. Before the problem is presented, however, some background information is in order on factors affecting the successful design of a transducer.

Strain Gage Commonly Used as a Transducer

A measurement system is comprised of three basic components: a transducer, a matching network, and a "readout" device. The transducer converts energy from one system to another system—for example, from a mechanical to an electrical system—following a proportional relationship. The matching network properly transfers the transducer signal to the readout device without overloading either the transducer or output device. The readout device, such as a recorder or meter, presents the data to the observer in some usable form.

There are different types of transducers, such as hydraulic, pneumatic, and mechanical, but the electro-mechanical type is the one most frequently used. This type of transducer converts physical phenomena to proportional electrical signals. There are, in turn, various types of electro-mechanical transducers, but the resistance-wire strain gage is more commonly used because it meets three basic transducer requirements—high sensitivity, an ability to sense static and dynamic strains, and high accuracy—and also has insignificant mass, small size, and is virtually unaffected by vibration.

Basically, the resistance-wire strain gage, or simply the strain gage, is used to measure strain. Because strain, the linear deformation of a material, can be caused by an external force acting on a material, it is possible to convert many different types of mechanical forces and motions to strain and, therefore, to a proportional electrical output signal. This can be proven by the fact that for many materials there is a proportional relationship between stress and strain, which can be stated algebraically as:

$$E = \frac{S}{\varepsilon} \tag{1}$$

where

E = Young's modulus or the modulus of elasticity (psi)

S = stress (psi)

ε = strain (in. per in.).

If a length of wire is fastened to the material such that the wire is strained equally with the material, the resistance of the wire will be directly proportional to its length and inversely proportional to its cross sectional area, as shown by the following basic relationship:

$$R = \rho \frac{L}{A} \qquad (2)$$

where

R = resistance of the wire (ohm)

ρ = resistivity of the wire material (ohm circular mil per ft)

L = length of wire (ft)

A = cross sectional area of wire (circular mils).

The resistance change of the materials used in strain gages is proportional to strain, although some other materials vary non-linearly.

Wheatstone Bridge Circuit Used to Measure Resistance Change

The constant ratio between unit resistance change and unit strain is known as the *gage factor* and is a measure of the sensitivity of the gage. The higher the gage factor, the higher the sensitivity. This ratio is expressed as:

$$G.F. = \frac{\frac{\Delta R}{R}}{\varepsilon} \qquad (3)$$

where

$G.F.$ = gage factor

ΔR = resistance change of the gage (ohm)

R = gage resistance (ohm)

ε = strain (in. per in.).

Strain ε is sometimes shown as $\Delta L/L$, the change in length per unit length.

If values for a typical strain gage are substituted into equation (3) and ΔR solved for, it will be seen that the resistance change is quite small. Typical values which can be substituted are: $G.F. = 2$, $R = 120$, and $\varepsilon = 200(10^{-6})$, a nominal value. Solving equation (3) for ΔR gives a resistance change of 0.048 ohms. Accurate measurement of such a small resistance change by an ohmmeter would require a very sensitive instrument. Such sensitive ohmmeters are available, but the more common practice is to use a Wheatstone bridge circuit, as shown at the bottom of the first column, to measure the resistance change.

The Wheatstone bridge circuit is composed of four resistances—R_1, R_2, R_3, and R_4—connected in a definite arrangement, and an excitation voltage and indicator device, often a galvanometer G. With the change in bridge resistance proportional to strain, the output voltage across G is proportional to strain. When no current flows in the indicator G,

$$\frac{R_1}{R_4} = \frac{R_2}{R_3}$$

or

$$R_1 = \left(\frac{R_2}{R_3}\right) R_4 \qquad (4)$$

where

R_1 = resistance of the strain gage (ohm).

If the value of precision resistor R_4 is known, and also the ratio R_2/R_3, then resistance R_1 can be accurately determined. There are different types of instruments available which can be connected across a strain gage bridge. In one such commercially available instrument the ratio R_2/R_3 is adjusted by a dial and when bridge balance occurs (no current through the indicator) the magnitude of the strain is indicated.

When strain is of a dynamic nature, the output voltage of the bridge also varies in a direct relationship with strain. In the case of dynamic strains a recording instrument is used to store the information either on chart paper or magnetic tape for later study.

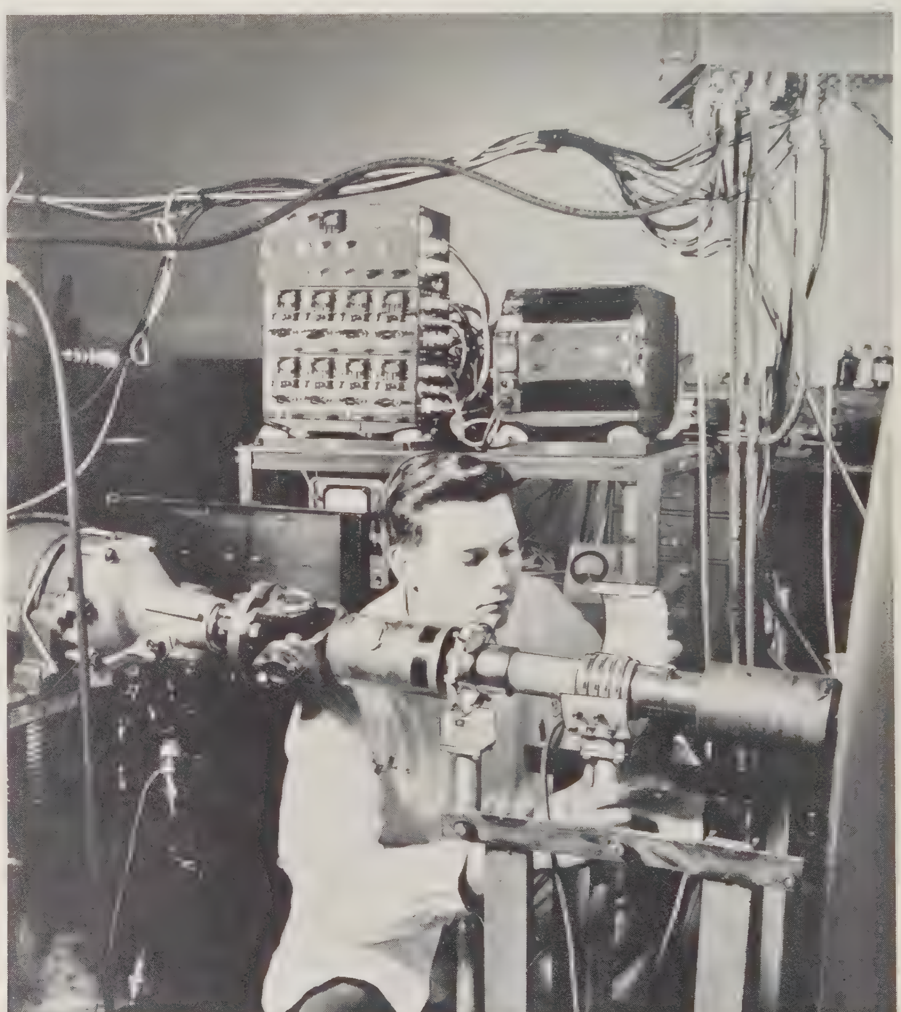


Fig. 1—Shown here is a typical installation of a strain gage, shaft-type torquemeter mounted between an automotive engine and a dynamometer. The technician is shown installing the slip-ring brush holder around the slip rings.

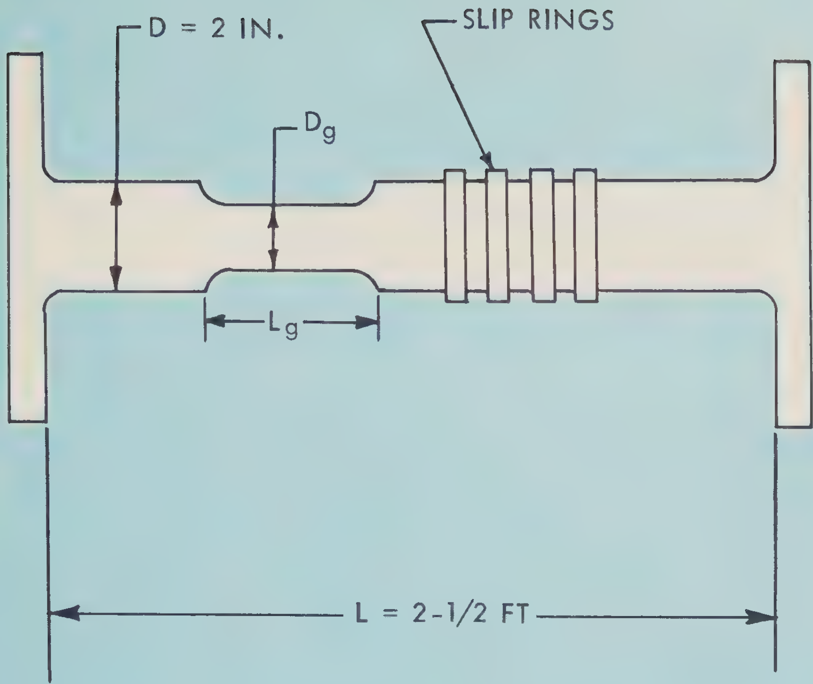


Fig. 2—One of the first steps in establishing the design parameters for a strain gage, shaft-type torquemeter is to determine the diameter D_g of the section of the shaft having a length L_g on which the strain gages are to be mounted. The non-gage section of the shaft has a two-in. diameter D and a length L of 2½ ft between couplings.

Multiple Strain Gages Give Accurate Readings

A major consideration when using just one strain gage is that temperature changes will affect the resistance of the gage and can cause inaccuracies if the proper steps are not taken—that is, frequent re-balancing. The usual procedure for temperature compensation is to use another strain gage for R_4 which is the same type as R_1. This second strain gage can be active, in which case it must be subjected to a strain opposite in sign to the strain R_1, or it can be a dummy gage with no strain on it. If R_4 is active the output voltage across the indicator will be doubled. In either case, R_1 and R_4 must be subjected to the same temperature such that they experience identical resistance changes and thereby cancel the temperature effect.

The more common arrangement is to use a Wheatstone bridge circuit with four active gages. This provides automatic temperature compensation while providing four times the output signal of one gage. In such an arrangement, the strain on R_1 and R_3 must be equal and opposite to that on R_2 and R_4.

Torque Measurements Made by Strain Gage Torquemeter

Strain gage bridges are frequently encountered in transducer application work. Using strain gages to measure deflection, twisting, or axial loading of mechanical members allows the measurement of such factors as velocity, acceleration, force, displacement, and torque which may actually produce the loading.

Torque measurements are frequently required in automotive work, especially during engine developmental tests. The dynamometer is commonly used for engine test work[1], but the torque measuring systems of the dynamometer, such as pneumatic cells or mechanical scales, do not have the frequency response often needed for observation of transient or dynamic performance. As a result, strain gage, shaft-type torquemeters are used.

As an example, in a durability test of an automatic transmission oil, the engine (coupled to a dynamometer) is cycled from idle to full throttle until the first transmission shift point is reached and is then throttled back to idle. To determine the nature of the load acting on the transmission accurately, a torquemeter is used to connect the transmission to the dynamometer (Fig. 1). With the torquemeter, the instantaneous fluctuations of load on the transmission can be measured, recorded on an oscillograph, and studied after the test is completed.

Problem

The problem is to establish the necessary design parameters for a strain gage, shaft-type torquemeter to be mounted between an automobile transmission and a dynamometer. The problem consists of three parts.

Part A—Determine the Gage Section Diameter of the Shaft

The torquemeter will use strain gages and slip rings. Construction details of the slip rings are *not* a required part of the problem. The torquemeter is to be made from a two-inch diameter solid shaft having a length L of 2½ feet between couplings (Fig. 2). The shaft material is S.A.E. 1020 cold rolled steel.

Determine the diameter D_g of the gage section of the shaft which will give maximum strain gage output under a load range of from 20 hp at 400 rpm to 350 hp at 1,850 rpm (transmission shift point) while meeting the following requirements:

- Maximum shear stress S_s not to exceed 30,000 psi
- Maximum tensile stress S_t not to exceed 35,000 psi
- Angle of twist Θ of the gage section of the shaft not to exceed 4° in 20 diameters of length.

The values chosen for maximum shear stress and tensile stress are typical for the specified shaft material. The yield strength in torsion is normally taken as approximately 0.6 that of the yield strength in tension, which is 60,000 psi for the specified material[2].

It will be assumed that there is no axial loading on the shaft. The modulus of elasticity in shear E_s is equal to $12(10^6)$ psi.

Part B—Specify the Proper Type of Strain Gages to Use and How They Should be Mounted and Wired

Assume that only four types of strain gages are available for use—A-7, C-7, AB-1, and CB-11 [3]. Select the appropriate type to use and indicate, by means of a wiring diagram, how they should be mounted on the shaft.

Direction of shaft rotation is clockwise, when viewed from the engine end of the shaft. The torquemeter will be used for a durability test lasting on the order of weeks. An oily atmosphere will be present while the test is being conducted.

Part C—Calculate the Output Signal Voltage

Calculate the signal voltage appearing across the output of the transducer during both minimum and maximum loads. Also, indicate the polarity. Use a strain gage excitation voltage of five volts d-c.

The solution to the problem will appear in the July-August-September 1960 issue of the General Motors Engineering Journal.

Bibliography

1. Knudsen, Roy F., "A Discussion of Present Day Dynamometers: Their Application, Operation, and Control," *General Motors Engineering Journal*, Vol. 4, No. 4 (October-November-December 1957), pp. 18-24.
2. Marin, J., and Saur, J., *Strength of Materials* (New York: The MacMillan Company, Second Edition, 1949), p. 85.
3. "SR-4 Strain Gages, Instruments, and Accessories," Specification and Price List No. 4310, February 1, 1959, Baldwin-Lima-Hamilton Corporation, Electronics Instrument Division, Waltham 54, Massachusetts.

Other related literature useful in the solution of this problem includes the following:

Perry, C. C., and Lissner, H. R., *The Strain Gage Primer* (New York: McGraw-Hill Book Co., Inc., 1955).

Murray, William M., and Stein, Peter K., *Strain Gage Techniques, Parts I and II*, published by the Massachusetts Institute of Technology, 1956.

Contributors to April-May-June 1960 Issue of GENERAL MOTORS ENGINEERING JOURNAL

RICHARD C. BALMER,

contributor of "Some Design Features of a New Series of V-6 and V-12 Gasoline Engines for Truck Application," is an engine design engineer for GMC Truck and Coach Division.

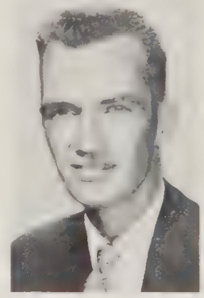
Mr. Balmer joined GM in 1932 as a General Motors Institute co-op student sponsored by GMC Truck and Coach Division. After graduating from G.M.I.'s four-year program, he was employed as a draftsman and continued his education by attending night classes at Wayne State University, which granted him a B.S. in mechanical engineering degree in 1941. Before being promoted to his present position in 1953, Mr. Balmer held the positions of senior layout man, senior designer, group leader, senior project engineer, and senior engineer.

Mr. Balmer is a member of the Society of Automotive Engineers and has served on the Plant Representatives Committee of the Detroit section. At G.M.I. he was a member of Alpha Tau Iota, engineering honor society.

BRYCE BEECHER,

contributor of "A Patent Problem Deriving from Machine Maintenance" and coordinator of this issue's "Notes About Inventions and Inventors," is a patent attorney in the General Motors Patent Section, Detroit Office. His current work is concerned primarily with patent matters in the field of hydraulics, including power steering. This work embraces patent prosecution, patent license and purchasing negotiations, infringement studies, and patent interferences.

Mr. Beecher attended Indiana University where he obtained the degrees of Bachelor of Science (1933) and Bachelor of Laws (1939). He joined General Motors in 1952. His prior experience included business, legal, and patent law work. He was employed as a sales correspondent at a chemical firm, and, after being admitted to the Bar, he served as counsel and assistant manager of a trade association type of organization. In the patent law field he gained experience in the patent departments of two major oil companies and as an associate with two patent law firms in New York and Boston. He is a registered patent attorney and a member of several state bars and of the Court of Customs Appeals and Patent Appeals.



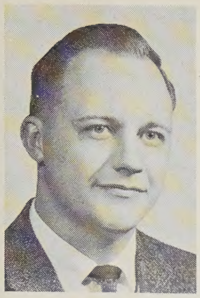
HOWARD A. GROOMBRIDGE,

contributor of "New Camera Takes True Pictures of Conditions Inside Cylinder Liner During Developmental Tests," is a supervisor of the Engine Test Group at Detroit Diesel Engine Division.

Mr. Groombridge joined Detroit Diesel in May of 1942 as a dynamometer operator. Six months later he entered military service with the Army Air Corps. He was separated from service in 1948 and returned to Detroit Diesel as a project mechanic. In 1951 he was recalled to active duty with the Air Force and served until 1953. Upon separation from service he returned to Detroit Diesel. He was promoted to junior engineer in 1954. He assumed his present position three years later.

Mr. Groombridge has attended Lawrence Institute of Technology. His technical affiliations include membership in the Society of Automotive Engineers. He is presently a major in the Air Force Reserve and serves as an environmental and specialized testing facilities officer with the Reserve's Research and Development Center.

WALTER H. LANGE,

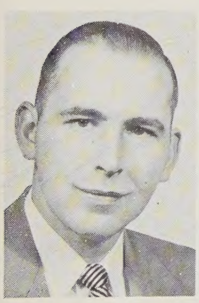


co-contributor of "Radioisotope Techniques Used to Measure Wall Thickness of Hollow Turbine Blades and Vanes," is a research physicist with the Physics Department of the GM Research Laboratories. Mr. Lange joined the Research Laboratories in 1953 as a project mechanic with the Physics Department. One of his earlier projects was an investigation of pulsating X-ray beams in connection with cancer therapy work. This work is presently being continued at the Kettering Laboratories, Yellow Springs, Ohio.

In 1956 Mr. Lange was transferred to the Physics Department's Isotope Laboratory. Two years later he was promoted to his present position, shortly after completing night school study for a B.S. degree from Wayne State University. His present work is concerned with the application of radioisotope techniques to the solution of various research problems received from some GM Divisions, the application of radiotracer techniques to a study of ball bearing wear and fatigue, and the application of autoradiography to studies of mass transfer and segregation.

Mr. Lange is a charter member of the Michigan Nucleonics Society and is also a member of the American Society of X-Ray Technicians and Alpha Epsilon Delta. Mr. Lange, who is on the teaching staff of the radioisotope school conducted by the GM Research Laboratories for GM Divisional personnel, has authored the chapters on Autoradiography and Radiochemistry Laboratory Techniques in the book "Radioisotopes in Industry."

DR. WILLIAM J. MAYER,



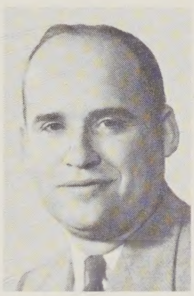
co-contributor of "Radioisotope Techniques Used to Measure Wall Thickness of Hollow Turbine Blades and Vanes," is a senior research scientist with the Physics Department of the GM Research Laboratories. He is a member of this Department's Isotope Laboratory. His present major projects include studies to find more useful industrial applications for radioisotopes. He also is concerned with research on ball bearing lubrication, production of short-lived isotopes, and metal thickness gaging problems.

Dr. Mayer received the B.S. degree from Wayne State University in 1944 and the Ph.D. degree from the same university in 1950. He is a member of the American Chemical Society and a charter member of the Michigan Nucleonics Society. He also holds membership in Sigma Xi and Phi Lambda Upsilon, honor societies.

Dr. Mayer has contributed three papers to the *Journal of the American Chemical Society* on the subject "Thermodynamics of Interface Formation." He also is a contributing author to the books "Radioisotopes in Industry" and "Nuclear Reactor Experiments."

Before joining the GM Research Laboratories in 1956 as a senior research scientist he was associated with the Argonne National Laboratory's Chemical Engineering Division.

GEORGE W. McDERMOTT,



contributor of "Applying Non-Destructive Test Standards to Improve Product Quality and Reliability," is supervisor of Statistics and Analysis, Delco-Remy Division. His responsibilities include supervision of a manufacturing statistical control group, development of in-plant training programs for the understanding and use of statistical quality control, technical supervision of non-destructive testing, and direction of new machine and process capability studies.

Mr. McDermott was appointed to his present position in 1959 following almost 20 years of work in various phases of inspection and quality control in connection with military and commercial products built by Delco-Remy. He joined the Division in 1933 as a production and assembly employe and became an inspection foreman in 1941. Subsequently, he held the positions of supervisor of magnetic inspection and quality control engineer.

He attended DePauw University and Purdue University. He also studied statistical methods of quality control in a special program at The Ohio State University and has attended several other educational programs on non-destructive testing techniques sponsored by equipment manufacturers. For several years, he has served as an instructor in quality control training programs for General Motors employes in various locations.

Technical societies of which he is a member include the American Society for Quality Control (fellow member), and the Society for Non-Destructive Testing.

CHARLES E. NEWMAN,

contributor of "Planning an Extraprofessional Reading Program for Engineers," is an instructor in the English Department and chairman of the Literature Committee at General Motors Institute. Besides teaching basic English courses, he is responsible for the design and revision of all literature courses. His previous work included the redesign of the senior level course "Directed Readings in Current Problems," and the formulation of the present required senior level literature course at G.M.I.

Mr. Newman joined General Motors Institute in 1953 after 12 years of teaching experience in high schools and universities including Washington University and Indiana University. He received the Bachelor of Science degree in education from The Ohio State University in 1939 and was granted the Master of Arts degree in English from Washington University, St. Louis, in 1947. Mr. Newman is a member of the Michigan College English Association and the GM Test Equipment Committee.

WALTER D. NOON,

contributor of "The Application of an Analog Computer to the Study of a Tractor-Trailer Suspension System," is supervisor of the Mathematical and Engineering Analysis Group at GMC Truck and Coach Division. This Group assists GMC Truck and Coach engineers in the application of mathematics and analog and digital computers to the

analysis and solution of engineering problems.

Mr. Noon joined General Motors in 1955 as a project engineer with the GM Manufacturing Development Staff. A short time later he was promoted to senior project engineer and headed the Analysis and Instrumentation Group of the Staff's Electronics Department. In 1958, Mr. Noon was transferred to GMC Truck and Coach and was given responsibility for the Mathematical and Engineering Analysis Group.

Mr. Noon is a 1951 graduate of the University of Michigan, where he was granted a B.S. degree in physics. He received the M.S. degree in physics from Wayne State University in 1953, where he is presently teaching evening classes in physics.

Prior to joining GM, Mr. Noon was employed by Lockheed Aircraft Corporation as a flight test analysis engineer. He also worked as a senior systems design engineer in electronics with Chance Vought Corporation.

Mr. Noon is a member of the GM Engineering Computation Committee.

ROBERT J. SCHMIDT, contributor of "Applying Methods Engineering and the Planning Team Approach at Frigidaire Division," is methods engineer and chairman of the electric range planning team at Frigidaire Division.

He joined Frigidaire in 1947 as a process inspector and was made junior process engineer in 1953. He was promoted to methods engineer in 1956 and in 1959 was given the added assignment of chairman of the electric range planning team. His current work is concerned with coordinating the planning efforts of the Methods, Manufacturing, Process, and Plant Layout Departments, in connection with electric range production. Previously, he directed methods planning for the assembly of washing machines, electric dryers, and built-in cooking units. Because of his experience in these activities, he assisted in the development and direction of the team approach to planning manufacturing operations at Frigidaire.

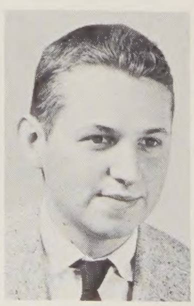
Mr. Schmidt attended the University of Dayton and has served as a trainer and speaker for the Ohio State Research Foundation, School of Logistics, Air Force Institute of Technology. He also is an instructor of methods engineering for the Self-Improvement Educational Program of the Dayton Foreman's Club.

WILLIAM L. SHELLY, co-contributor of "Radioisotope Techniques Used to Measure Wall Thickness of Hollow Turbine Blades and Vanes," is a senior experimental engineer in the Applied Physics Section of Allison Division's Research Department. At present, he is in charge of this Department's Radioisotope Laboratory and is responsible for carrying out such projects as the application of radiotracer techniques to a study of oil seal leak problems and a study of bearing wear.

Mr. Shelly joined Allison in 1948 as an engineering technician in the Electronics and Parts Test Department. Successive promotions to detail engineer and experimental engineer led to his present position which he assumed in 1957. His previous major projects were in connection with vibratory stress analysis and fatigue of metals. In 1958 Mr. Shelly completed a course conducted by the Isotope Laboratory of the GM Research Laboratories in the application and handling of radioisotopes. A short time later he aided in the design and building of the Allison Radioisotope Laboratory.

Mr. Shelly received the A.B. degree from DePauw University in 1947. Prior to joining Allison, he was a graduate assistant at Purdue University. He is currently teaching undergraduate physics courses at Butler University.

Mr. Shelly is a member of the American Nuclear Society and the Allison Division Isotope Committee.



WILLIAM L. SPRAGUE, contributor of "Some Advantages Provided by Transistors When Used in Industrial Inspection and Control Systems," is a project engineer with the GM Manufacturing Development Staff. He joined the Electronics Department of the Staff's Process Development Section in 1957 as a junior engineer. He assumed his present position in 1959.

Mr. Sprague's current major projects include circuit design and development of electronic inspection and control equipment. In recent months his work has been mainly with transistorized equipment.

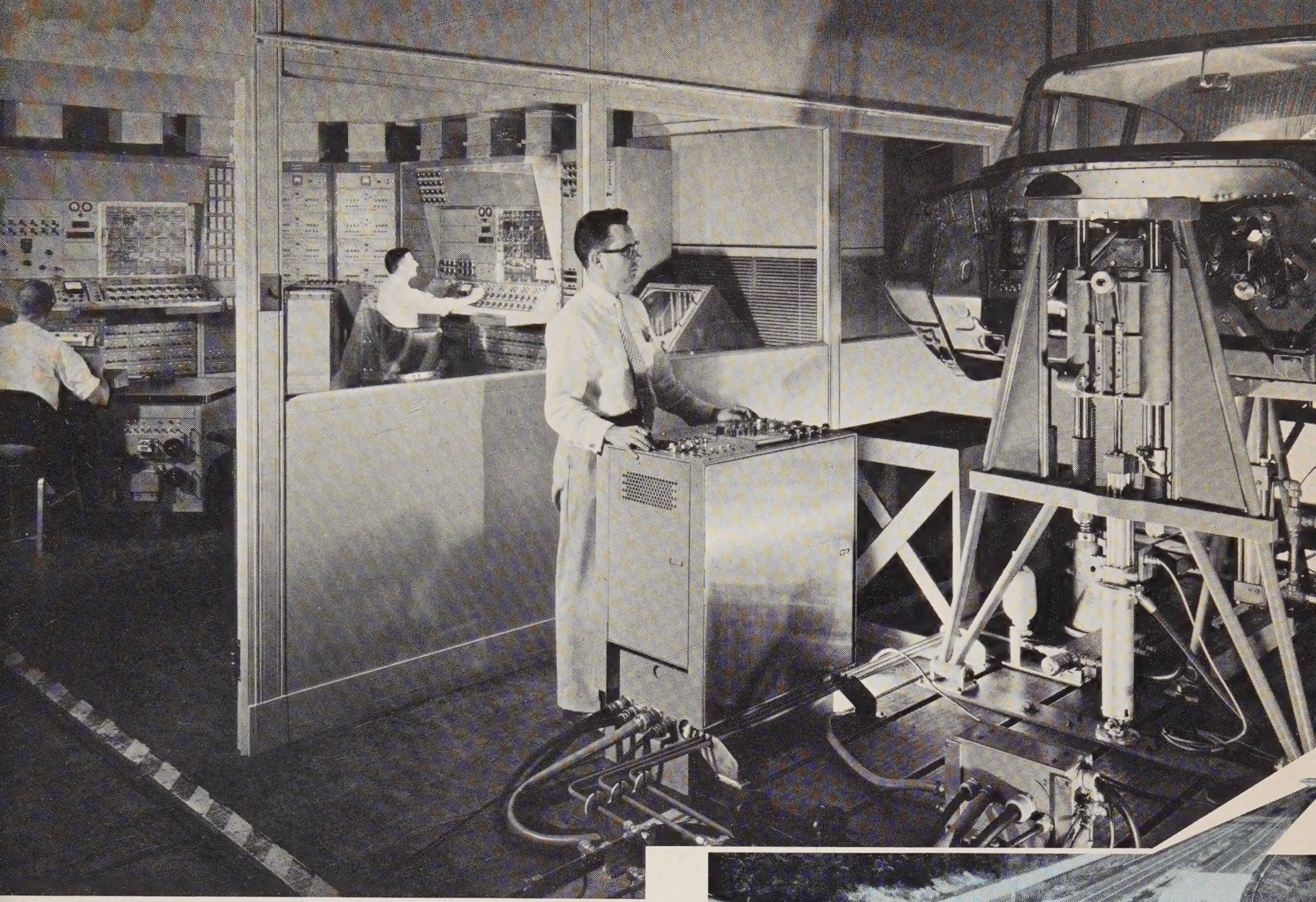
Mr. Sprague received the B.S.E.E. degree from Purdue University in 1957. While attending Purdue he had summer employment as a junior engineer with the Packard Electric Division.

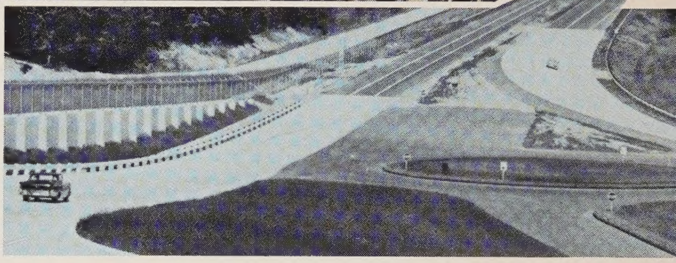
He is a member of the Institute of Radio Engineers, the American Institute of Electrical Engineers, and Eta Kappa Nu and Tau Beta Pi, honorary societies.

ERNEST W. UPTON, contributor of the problem "Determine the Angular Setting of Spokes Used in the Second Turbine of an Automatic Transmission," and the solution appearing in this issue, is a section engineer with the GM Engineering Staff's Transmission Development Group. He presently is in charge of the design and development of hydrodynamic drive units. This responsibility also includes supervision of testing and vehicle performance studies related to these units.

Mr. Upton graduated from the University of Denver in 1941 with a B.S.E.E. degree. In 1943 he was granted the B.S.M.E. degree from the Massachusetts Institute of Technology. He then joined the Engineering Staff as a junior engineer. He shared in the early developmental work on automatic transmissions for passenger cars and heavy duty transmissions for military applications. He also assisted with the design and construction of hydrodynamic drive exhibits for the GM Motorama shows.

The technical affiliations of Mr. Upton include membership in the S.A.E. He also is a member of Sigma Pi Sigma, Mu Sigma Tau, and Phi Beta Sigma, honorary societies.





ENGINEERING

ASSIGNMENT IN GM

The techniques of mathematical analysis and "driver feel" have been combined by the General Motors Research Laboratories into the equipment shown here for studying the ride motions of a moving car. This laboratory work provides information which is important in the design of new steering and suspension systems.

Research engineers recently developed three equations (incorporating 20 parameters) describing the lateral response of a vehicle. The parameters are varied and the equations solved on computers to evaluate proposed designs. Another development was the test equipment shown above, called the Ride Simulator, which reproduces the road response of a real car. Now, engineers save time by making preliminary analyses of complex suspension problems which formerly had to be solved by building prototype cars and road testing them.

To use the Ride Simulator, test personnel first tow an instrumented wheel over actual roads to record on magnetic tape a variety of road waves. The tape then is played into the analog computer (background). The computer takes into account preselected suspension characteristics and supplies output voltages to electro-hydraulic servo-mechanisms which reproduce road effects on the car body and passenger. Through a feedback system from the brake pedal and accelerator, the driver also can simulate his own control of the car speed.

Conducting the test shown here are: (center) Robert H. Kohr, supervisor, Vehicle Dynamics Section, Engineering Mechanics Department; (right) William J. Kelly, research engineer; (background left) Richard E. Rasmussen, research engineer; and (background right) Harold J. Schell, research engineer.

Mr. Kohr received the B.S.E. (physics) degree in 1950 and the M.S.E. (engineering mechanics) degree in 1951 from the University of Michigan. He joined the GM Research Laboratories in 1954 as a research engineer and was promoted to his present position in 1957.

Mr. Kelly joined the Research Laboratories as a college graduate-in-training in 1955 after graduation from the University of Michigan with the M.S.E. degree (engineering mechanics). After one year in the training program, he was made a research engineer in the Engineering Mechanics Department.

Mr. Rasmussen joined General Motors in 1953 as a cooperative engineering student at General Motors Institute. He earned the B.M.E. degree in 1958 and joined the Research Laboratories as a research engineer. Currently, he is on an educational leave of absence to obtain the M.S. degree at the University of Michigan.

Mr. Schell received the B.S.M.E. degree in 1956 from Pennsylvania State University. At present, he is attending night classes at Wayne State University working for the M.S.M.E. degree. He joined the Research Laboratories in 1956 as a college graduate-in-training and was advanced to his present position in 1957.

GENERAL MOTORS ENGINEERING JOURNAL